UNITED STATES ARMY

EDUCATIONAL MANUAL No. 16

STORAGE BATTERY CARE AND MAINTENANCE

EDUCATION AND RECREATION
SPECIAL SCHOOL
CAMP GRANT, ILLINOIS
1920

U. S. ARMY
E. AND R. SPECIAL SCHOOLS

INTRODUCTION

For many years the army has been developing a system of training for technicians. The Engineer School at Washington Barracks, the Coast Artillery School at Fortress Monroe, and other post schools had before the war practical and successful schools for this purpose. The School of the Line at Fort Leavenworth had also developed a sound method of teaching based upon the same fundamental conception known throughout the army as the applicatory method.

During the war, the army was compelled to train rapidly more than 1,250,000 men in technical lines. To do this, special schools were established by every special service and in most of the large camps. When the capacity of these schools was found inadequate to meet the demand, the National Army Training Detachments were established at civilian institutions, but under military control. To meet the needs of the situation, the previous practices of the army rapidly developed into a well defined system of intensive training which attained a large degree of success.

Because of this experience during the war, the army is now continuing its system of vocational training and is endeavoring to place it on a sound and efficient basis. The results of these efforts are contained in this series of manuals. These embody the results of the war experience and of a careful study of that experience since the signing of the armistice.

The army applicatory method is designed to train the type of soldier required in modern warfare. This requires the development of good coordination of mind and body and the ability to think quickly and independently in emergencies. Since every soldier in battle is almost certain at some time to be placed in a position requiring independent action and qualities of leadership, it is essential that the training system of the army should develop independence, initiative, resourcefulness and powers of quick and sound judgment as far as possible in every man.

There are two fundamental principles underlying the applicatory method. The first is that the best method of training men to think is to place them in real situations which challenge their abilities and make thinking necessary. The second is that progress is best measured by objective standards which reveal what the man can actually do. A new technique has been developed to express these two principles in school practice and this is presented in these manuals.

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These instruction manuals have been developed at the Education and Recreation Special School at Camp Grant, Illinois, during the past winter by a group of civilian experts, under the direction of Dean R. W. Selvidge, of the University of Missouri. The manual for Storage Batteries has been prepared by Mr. A. L. Pearson. It is submitted to the service for criticism and suggestion with the firm conviction that if the instructors in army schools will follow the general methods herein indicated, using their own jobs adapted to their local situations, the most satisfactory results will be secured both for each individual school and for the army as a whole.

C. R. Mann,
Chairman, Advisory Board.

Washington, 1920.

SB—2—10M—9-20

AUTOMOTIVE DEPARTMENT

Storage Battery Care and Maintenance

Requirements of Storage Battery Workers and the Possibilities of the Trade

A man who undertakes storage battery work must be of sound health, ambitious and industrious. In order to make a success of his work he must know something of the elementary theory of storage batteries. The educational requirements for an ordinary battery mechanic are not high. The requirements for an expert are greater, as a considerable amount of technical knowledge is necessary. The student, therefore, should have at least a grammar school education and supplement his work in the shop by outside study. It is possible, however, for the man with limited education to advance by continuing his studies in general education. It is the purpose of this course of instruction to combine the study of the elementary theory of the storage battery with practical work in the shop on a productive basis.

The duties of a storage battery worker involve such operations as putting new batteries in service, charging, operating charging equipment, tearing down, assembling, cleaning, restoring sulphated batteries, testing batteries and preparing electrolyte.

The increasing number of automobiles and trucks and the use of electrically driven trucks and tractors for handling of freight have opened up a field in storage battery manufacture and engineering which has grown rapidly within the past few years. There is, therefore, a great demand for men skilled in this line of work which will provide employment the year round with wages varying from $125 to $250 per month, depending upon the skill and ability of the worker. One who has completed this course of study should be able to obtain a responsible position in a first class battery service station or in a manufacturing plant.

The conditions in storage battery work which would affect the health of operatives are practically negligible, provided ordinary high standards of cleanliness and ventilation are maintained.

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SUGGESTIONS TO INSTRUCTORS

In the productive operations of a trade are found the best conditions for teaching a man that trade. We have, therefore, so arranged the material in these manuals that a man may readily use it to analyze his job and to plan the order of procedure in doing it. It is this ability to analyze and plan a job that forms the chief mark of distinction between the high-grade and low-grade mechanic.

The Analysis of a trade is a list of the things a man must be able to do in order to be a proficient worker in the trade. It is, therefore, a list of the things we must teach him. The items appearing in this analysis are called Unit Operations. By this term we mean the fundamental mechanical processes of the trade which occur in practically identical form in many jobs. Thus, soldering is considered a unit operation in the tinners trade, sawing a unit operation in carpentry, and plain seaming a unit of operation in canvas working.

In analyzing a trade into its unit operations certain minor operations are omitted when such operations appear too simple to require instruction as to method of performance. The number of unit operations may be increased by sub-division of any one of the operations now assumed to be a unit. The instructor should make further sub-divisions if in his experience it appears to be desirable. In this he should be guided by what the mechanic ordinarily regards as a unit in his work. A job is a specific task involving one or more of these unit operations.

The Operation Sheets give specific and concise directions for the performing of the unit operations. References are given at the beginning of the Operation Sheet. It is expected that copies of all reference material referred to in the Operation Sheets will be available at all times in the shop or classroom.

The directions on the Operation Sheets are followed by a series of questions. These questions are designed to direct the attention of the student to important points covered in the references and to direct his thinking to the reasons for performing the operations in the way indicated. They also serve as a concise review of the principles involved in the right performance of the unit operation. It will be noted that no questions are directly answered in the directions. Instructors may find it necessary to supplement this list of questions.

The Information Sheets deal with the general principles lying back of the work of the trade rather than with manipulative processes. They treat more particularly of the science, mathematics and drawing commonly classed under the head of collateral information. This information is set down definitely, briefly and without discussion. It is followed by a

series of questions calculated to arouse the interest of the student and to serve as a guide in reading available reference material. It is intended that the work of the shop shall be supplemented by free discussion with the class during the problem hour.

Vocational Problems are problems in science, mathematics and drawing which arise frequently in the trade. These problems the proficient worker must be able to solve. In the short time needed to learn the manipulative processes of a trade he will hardly meet with enough of these problems to find sufficient practice to enable him to solve them with promptness and accuracy. It is the purpose of the Information Sheets and Vocational Problems to give him the practice necessary for him to proceed with confidence to the solution of the problems of his trade. This practice should be given on problems directly related to the trade in which he is engaged.

Since the Analysis Sheet constitutes a list of the things a man must be able to do in order to be proficient in his trade, it will be seen that the time element is not to be considered. The only element to be considered is his ability to perform these operations. For example, one man may learn all the operations of his trade in six months where another may require a year to reach the same standard of proficiency. The whole fabric of Trade Analysis, Operation Sheets, and Information Sheets is designed to afford the greatest flexibility in the accommodation of the work to the requirements of different individuals.

In teaching the manipulative processes of a trade classes should not exceed twenty men; twelve to fifteen is a more desirable number. In order to handle classes in trade work with the greatest degree of ease and success, instructors will find it desirable to divide the class into small groups of not more than four or five men. A leader should be appointed for each of these groups and the instructor should deal chiefly with these leaders. In choosing the group leaders the instructor should have in mind only their knowledge of the particular kind of work in hand, but also their personality and ability to lead their groups. General directions should be given to the group leaders and they should be held responsible for the conduct of the men and the care of tools and materials used by their groups. By meeting these group leaders a few minutes each day the instructor can soon develop in them a sense of responsibility and power of leadership. Such a plan will simplify the whole problem of instruction.

It is important that the instructor have a complete list of the jobs to be done about the camp or post that will be available for his class. The instructor should analyze each of

these jobs carefully and list each of the operations involved. To this list of operations should be attached a list of materials and tools required to do the job. The list of jobs should be kept on file so that they may be assigned to men at any time.

The men in school should never be called upon to do a job that has not first been approved by the instructor. A teacher should never approve a job which does not contain the elements in the performance of which he desires to instruct. Nothing can so demoralize a class as to have someone who is unfamiliar with the instructor's plan direct him to take his class and perform a piece of work which he has had no opportunity to plan and which does not fit into his scheme of instruction.

The instructor should talk things over with the members of his class to give them a thorough understanding of the general plan of the work before they start on their job.

Beginners should be given jobs which involve only a few simple operations. Along with the assignment of a job a man should be given a trade analysis sheet and be asked to look over the job and check on the trade analysis the unit operations involved in its execution. After this list is checked the instructor should examine it and compare it with his own scheme for doing the job. If the list of unit operations checked contains operations which should not have been checked, or if operations have been omitted which should have been checked, the man should be asked to consider the job carefully again and to discover, if possible, his error. Perhaps ignorance of certain requirements of the trade may result in the omission of some of the unit operations and a casual question or two from the instructor should lead the man to succeed in his analysis. It may be necessary also to explain to the new man the meaning of the terms used in the analysis.

Having analyzed the job for the unit operations involved the next duty of the man is to plan the procedure for doing it. To do this, he should list the operations in the order in which they occur in the execution of the job. In some instances it will be found that a number of operations will occur simultaneously. In that case it should be so indicated. It is often true that different orders of procedure are equally good. The instructor should, therefore, question the man concerning his reasons for proceeding in the way he has indicated and, if he gives good reasons, he should be permitted to follow his own plan even though it is not the usual order.

The importance of such an analysis and plan can scarcely be overestimated. The learning of manipulative processes, while important, constitutes but one part of the learning of the trade. The man who does not learn to analyze his job and to

UNIT OPERATIONS	ORDER OF PROCEDURE
12. Starting and adjusting a mercury arc rectifier.	
13. Starting and adjusting a tungar rectifier.	
14. Making diagram showing relative location of cells, etc.	
15. Tearing down a battery.	
16. Assembling a battery.	
17. Lead burning by means of— Illuminating gas and oxygen. Hydrogen and compressed air. Acetylene and air. Electric arc.	
18. Cleaning a battery.	
19. Putting a battery in storage. Wet storage. Dry storage.	
20. Restoring a sulphated battery.	
21. Preparing electrolyte.	
22. Correcting hydrometer readings for temperaature.	
23. Adjusting specific gravity of a given quantity of electrolyte to a specific different value.	
24. Testing a battery for capacity. Ampere-hour capacity. Watt-hour capacity.	
25. Testing plate capacity (Cadmium tests).	
26. Testing a battery for efficiency. Ampere-hour efficiency Watt-hour efficiency. Voltage efficiency.	

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AUTOMOTIVE DEPARTMENT

STORAGE BATTERY CARE AND MAINTENANCE

Unpacking a new battery

References:

Circular No. 92, Bureau of Standards, p. 53.

Directions:

1. Keep the battery upright to prevent spilling electrolyte.

2. Remove top of packing case, using a box opener if available. Such a tool saves time.

3. Remove excelsior and packing from the top and sides of tray.

4. Remove the battery from the packing box and take off the wrapping paper.

5. Remove, or open, the vent plugs and note the level of the electrolyte.

6. Examine the battery for damage in transit, such as broken cells, which may be indicated by low electrolyte in a particular cell, or by wet packing material at bottom of tray.

7. Report any damage to the foremen for adjustment with the carrier.

8. Number battery for identification.

9. Put battery in store room, if not to be put into service at once.

Questions:

1. *Why is the packing material discolored and rotten when wet with electrolyte?*
2. *Why is paraffined paper used to cover the top of the battery?*
3. *Why note the level of the electrolyte? How high above the top of the plates should this be?*
4. *How would you locate a broken or cracked jar?*
5. *What would you do, should you find a broken jar?*
6. *Why is the packing case made with gable shaped top?*
7. *Why are slats used as the sloping sides of the top instead of solid covers?*

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AUTOMOTIVE DEPARTMENT

STORAGE BATTERY CARE AND MAINTENANCE

Testing strength of electrolyte
(Use of Hydrometer)

References:

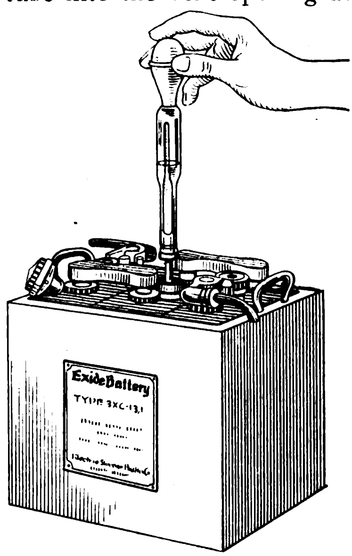
Circular No. 92, Bureau of Standards, pp. 37, 43.

"Exide" Manual, Electric Storage Battery Co., Form 1296, 1919, pp. 11, 13, 21, 27.

Directions:

1. Remove vent plug.

2. Squeeze the rubber bulb of the syringe to expel the air and insert the rubber tube into the vent opening as far as it will go.

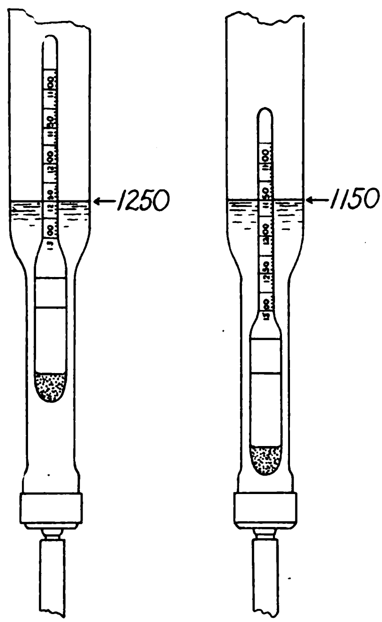


Taking hydrometer reading
Fig. I

3. Hold the syringe in a vertical position, Fig. 1, and release the pressure on the bulb slowly, thus drawing some of the electrolyte into the glass barrel of the syringe. When a sufficient quantity of electrolyte has entered the syringe the hydrometer will float.

4. Hold the syringe vertical with the top of the electrolyte on a level with the eye, and with the hydrometer floating freely, take

the reading. The reading is the number on the stem at the surface of the electrolyte. Thus in Fig. 2 the reading at the left is 1.290 and at the right 1.150.



Hydrometer Readings
Fig. 2

5. Return the electrolyte to the cell by firm pressure on the bulb.

6. Take the temperature of the electrolyte.

Note.—An examination of the hydrometer shows that there are ten equal spaces marked off on the stem between numbered points as 1.250 and 1.300, each representing five points. The scale is read from the top downward. Had the hydrometer floated so that the surface of the electrolyte was at three spaces above 1.250, the reading would have been 1.265. The value for a fully charged battery is 1.285 and for a discharged battery 1.150 with the temperature of the electrolyte at 25 degrees centigrade. The specific gravity is different at different temperatures and it is best practice to make corrections if the temperature is more than 10 degrees above or below 25 degrees, that is 35 degrees or 15 degrees centigrade.

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Questions:

1. *What is specific gravity?*

2. *Why does the hydrometer sink to a lower level in the electrolyte with low specific gravity?*

3. *What do the readings of the hydrometer mean to you?*

4. *When should hydrometer readings be taken?*

5. *When may hydrometer readings give false indications?*

6. *Would you take a hydrometer reading just after adding water to the battery?*

7. *Why are hydrometer readings different at different temperatures?*

8. *Why should the pressure on the bulb be released slowly in drawing electrolyte into the syringe?*

9. *Why should the syringe be held vertical with the hydrometer floating freely? Why with the level of the electrolyte as a level with the eye?*

AUTOMOTIVE DEPARTMENT

Storage Battery Care and Maintenance

Adjusting level of electrolyte

References:

"Exide" Manual, Electric Storage Battery Co., Form 1296, 1919, p. 25.

Bulletin 850X, Edison Storage Battery Co., p. 12.

Directions:

1. Remove the vent plugs or open vents and note the level of the electrolyte. The depth of the electrolyte over the top of the plate may be determined by inserting a small glass tube—say 1/8 inch diameter—vertically through the filling aperture until it touches the top of the plates Wet the tip of the finger, place it over the end of the tube and withdraw the tube. The electrolyte will stand at a height in the tube equal to the depth above the top of the plate. Allow the electrolyte to flow back into the cell by removing the finger from the end of the tube.

2. If the level is uniformly low in all cells, fill with distilled water only, up to the proper level for the particular type of cell, usually about 3/8 inch above top of plates. The hydrometer syringe is convenient for this purpose.

3. If the level is higher in some cells than in others, fill with electrolyte of specific gravity 1.285.

Questions:

1. *How often should water be added to the batteries?*
2. *What effect have long daylight runs on the necessity for adding water? Why?*
3. *When is the best time to add water? Why?*
4. *What may happen if the water is not properly mixed with the electrolyte?*
5. *What is the proper level for the electrolyte in a U. S. L. battery? In an Exide battery?*
6. *What devices are there for filling Edison batteries with water? Describe their operation.*
7. *What is the common expression for filling a battery with water to make up for loss of electrolyte by evaporation?*

AUTOMOTIVE DEPARTMENT

Storage Battery Care and Maintenance

High rate discharge test

References:

"Exide" Manual, Form 1296, 1919, p. 52.

Waite, C. A., The Automobile Storage Battery, 1919, p. 188.

Directions:

For an Incoming Battery

1. Attach a lead tag to a handle of the battery by means of wire, as a means of identification.

2. Record this number on the shop card provided for this purpurpose, together with such other data as is listed on the card.

3. Take a hydrometer reading of each cell and the temperature of one cell and record them.

If the hydrometer readings are within 50 points of each other and all below 1.200 it is an indication that the battery probably requires an equalizing charge only, with a possible adjustment of the specific gravity of the electrolyte.

If the readings are above 1.200 or one cell differs from the rest by 50 points or more, make the discharge test.

4. Determine the value of the discharge current in amperes on the basis of 20 amperes per positive plate. Thus, for a 9 plate battery which has 4 positive plates the discharge current is—

$$4 \times 20 = 80 \text{ amperes}$$

The value of the discharge current is independent of the number of cells in the battery.

5. Take the battery to the high rate discharge stand.

6. See that the switch is open and that the resisting is all in; that is, that the carbon blocks of the rheostat are in loose contact.

7. Connect the cables from the stand to the battery by snapping the clips on the cable firmly over the terminals of the battery. The positive terminal of battery is to be connected to the positive cable.

8. Close the switch quickly and note the reading of the ammeter.

9. Increase the current to the value determined in direction 4 by turning the screw at the right hand end of the rheostat to the right, thus putting pressure on the carbons.

10. Hold the current constant for about 15 seconds and read and record the voltage of the individual cells.

11. Stop the discharge by opening the switch first, loosening the pressure on the rheostat second.

12. If the voltage readings are within 0.10 volt of each other, the battery needs an equalizing charge and an adjustment of the electrolyte as stated in direction 3.

13. If the voltage readings differ by 0.10 volt or more and the battery is nearly charged there is some internal trouble in the cell having the low voltage.

With a discharged battery, the difference in voltage will be greater, depending upon the state of discharge and experience only can be used as a guide in drawing correct conclusion.

For an Outgoing Battery

14. Make the discharge test immediately before putting the battery in service.

15. There should not be a difference of more than 0.10 volt between any two cells and no cell should show less than 1.75 volts. Voltage readings are to be made with current flowing.

16. If the voltage of one cell is 0.10 volt or more below that of the others, that cell still needs attention.

Questions:

1. *Why is a lead tag used, rather than one of some other material?*

2. *What can cause variations in the specific gravity of different cells in the same battery?*

3. *What is the principle of operation of the carbon block rheostat? What are its advantages?*

4. *What internal trouble may be indicated by a low voltage across a cell?*

5. *Why are the voltage readings made when current is flowing?*

6. *Why is it desirable to make a high rate discharge test immediately before putting a battery in service?*

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AUTOMOTIVE DEPARTMENT

STORAGE BATTERY CARE AND MAINTENANCE

Charging a battery by the constant current system

References:

Circular No. 92, Bureau of Standards, 1920, p. 44.

Bulletin No. 177, Electric Storage Battery Co.

Waite, C. A.. The Automobile Storage Battery, 1919, p. 167.

Bulletin 850X, Edison Storage Battery Co., p. 8.

Bench charge

(With rheostat for adjusting current)

Directions:

1. Clean top of battery thoroughly.

2. Take readings of specific gravity and temperature of electrolyte and record them on the proper form.

3. Remove the vent plugs and fill each cell with distilled water to the proper level, then replace plugs.

4. Determine the charging rate to be used. This may be found on the name plate of the battery.

5. Examine the charging circuit and see that switches are open and that the resistance is all in.

6. If more than one battery is to be charged on one circuit, connect the positive terminal of one battery to the negative terminal of the next and so on, thus forming one battery of a greater number of cells. The positive battery terminal is marked POS or + or painted red; the negative terminal is market NEG or — but usually not painted.

7. Connect the positive terminal of the battery to the positive charging wire and the negative terminal to the negative charging wire. When more than one battery is to be charged on one circuit, the positive and negative terminals of the group are the termals to be used.

8. Close the switch with a quick, positive movement and note the current indicated on the ammeter. Adjust the current to the value determined in direction 4 above by cutting in resistance, if it is too high, or cutting out resistance, if it is too low.

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Bench charge

(With rheostat for adjusting current)

9. Continue the charge at the above rate until all cells are gassing freely and until the hydrometer reading and voltage of each cell are about constant. For a completely discharged battery this will be when the number of ampere—hours put in is from 90% to 100% of the ampere-hour capacity of the battery.

10. Reduce the current to the finishing rate and continue the charge for 1½ to 2 hours longer.

11. Take readings of the specific gravity and temperature of the electrolyte and individual cell voltages and record them on the proper form. The specific gravity should be about 1.285 corrected to 25 degrees centigrade and the voltage not less than 2.4 volts per cell. The battery will then be ready for service.

12. Disconnect the battery from the circuit by first cutting in all the resistance and then opening the switch with a quick positive movement.

13. Do not allow the temperature of the electrolyte, for any charge, to rise above 43 degrees centigrade, (110 degrees Fahrenheit), reducing the current or interrupting the charge, if necessary. The charge is to be continued as soon as the temperature has come down below the safe limit.

With incandescent lamps for adjusting the current

14. Connect up a sufficient number of lamps on the direct current circuit to allow the current determined in direction 4 above to flow, and proceed in accordance with the above directions.

15. Hold the current constant by cutting lamps in or out of circuit. It is to be noted that the current will gradually become less as the charge progresses, requiring additional lamps to be cut into the circuit in order to hold the current constant.

Questions:

1. *How do you determine whether or not the battery needs charging?*
2. *What precautions must be taken when using hydrometer readings as indications of the condition of a battery?*

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3. *What indication of state of charge is given by an open circuit voltage reading? Closed circuit reading?*

4. *How constant must the current be held during the charge? Why?*

5. *Do you need to read the temperature and specific gravity of all cells during charge? Of only one cell? Why?*

6. *Should you correct electrolyte condition before charging? If so, how can you be sure of a true reading of specific gravity after water is added?*

7. *Why is a so-called finishing rate used?*

8. *How do you know when to reduce the current to the finishing rate?*

9. *How can you make sure of having the positive side of the line connected to the positive side of the battery? Are the terminals marked?*

10. *What would happen to the battery if you had wrong polarity in charging?*

11. *What will you do if the temperature rises above* 43 *degrees Centigrade? Why?*

12. *How can you tell when the charge is complete?*

13. *If the battery is only partially discharged when placed on charge, how long will you charge it?*

14. *What is the first thing to do when battery is received from a car to be charged? Why?*

15. *Will a battery increase in capacity if left standing unused? If so, why?*

16. *How would you treat the battery if it has been overdischarged?*

17. *What is indicated if the battery will not take its charge? What would you do?*

18. *What will happen if a discharged battery is allowed to stand some time before charging? Why?*

19. *What value of resistance would you use to charge a* 6 *cell battery at* 20 *amperes from a* 110 *volt direct current circuit?*

20. *How would you arrange a circuit to charge a 6 cell battery at 10 amperes with lamp as resistance and a 110 volt direct current circuit? One a 220 volt circuit? One a 550 volt circuit?*

Equalizing Charge

1. Give the battery a bench charge and at the end of it reduce the current to one-half the value of the finishing rate.

2. Continue the charge at this rate until all cells are gassing freely and uniformly and until three consecutive readings of the specific gravity and voltage of each cell taken at half hour intervals show no increase.

3. If the specific gravity of the electrolyte in any cell rises above 1.300, adjust the strength of the electrolyte to 1.285 and continue the charge for ten hours longer.

Questions:

1. *When is an equalizing charge necessary? Why?*
2. *Why is the charging rate low?*
3. *Is the voltage higher or lower at the beginning of the equalizing charge than at the end of the bench charge? Why?*
4. *Does the voltage rise during the equalizing charge? Why does it become constant at the end of the charge?*
5. *How would you adjust the strength of the electrolyte, if it were found necessary to do so?*
6. *What effect does strong acid have on the battery?*
7. *What is indicated when the readings of the hydrometer are 1.300 or higher?*

Boosting charge

Charging Lead Acid Batteries at Abnormal Rates

1. Determine the number of ampere hours discharged from the battery. This may be found by reading the ampere hour meter on the truck, if there is one, or if not, by multiplying the number of hours the truck has been in operation by one-half the normal 5 hour discharge rate of the battery. For example: Truck operated from 7:00 A. M. to 12:00 M = 5 hours. Battery, normal discharge rate = 45 amperes. Ampere hours discharged $= 5 \times \frac{45}{2} = 112.5$ ampere hours

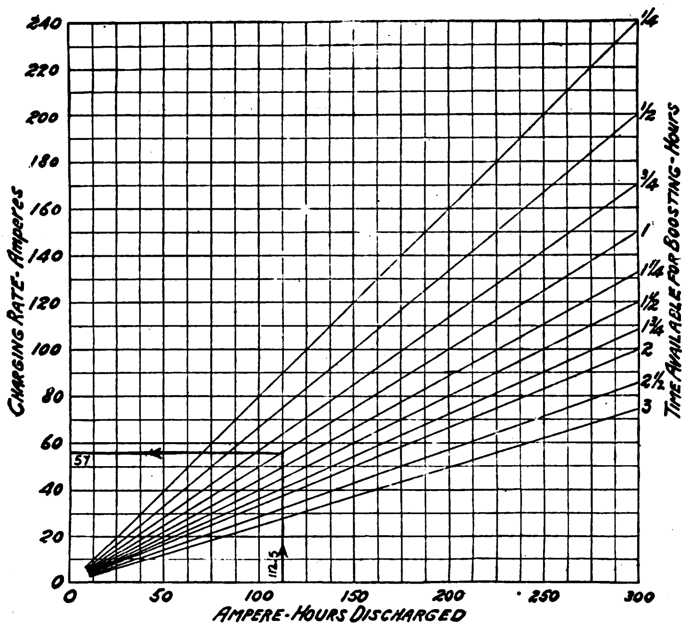

Fig.3

2. Refer to the chart, Fig. 3, find 112.5 on the horizontal scale numbered "Ampere-Hours Discharged"; follow vertically from this point to the sloping lines marked "Time Available for Boosting" and stop at the one corresponding to the time, say 1 hour; follow horizontally from this point to the vertical scale at the left marked "Charging Rate" and read 57 amperes.

3. Connect the battery to the circuit at this charging rate and continue the charge for 1 hour.

4. A charging plug receptacle is provided on vehicles and locomotives to which the charging line is connected.

5. Rates for Boosting Edison Batteries—5 minutes at 5 times normal rate; 15 minutes at 4 times normal rate; 30 minutes at 3 times normal rate; 60 minutes at 2 times normal rate. Frothing at the vent is an indication that the charge has been carried too far. Discontinue the high rate immediately.

Questions:

1. *What is a boosting charge?*
2. *Can a bosting charge best be accomplished by the constant current method or by the constant potential methods?*

3. *Under what operating conditions may a boosting charge be desirable?*

4. *Does the rate of charging have any relation to the ampere hour discharge capacity of the battery? Why?*

5. *What are some objections to high charging rates?*

6. *What consideration of economy enters into the answer to question 5?*

7. *What effect has gassing on the life of a battery?*

8. *What is the maximum rate at which a battery can be charged without excessive gassing?*

Conditioning of Initial Charge

1. Allow the battery to stand from 10 to 15 hours after filling with electrolyte before giving it a conditioning charge.

2. Add more electrolyte to restore the level, if it has fallen, and replace filling plugs. Never charge with filling plugs out or loose, as flooding may result.

3. Determine the charging rate and length of time the charge is to be continued. This may be found in the instruction book of the battery manufacturer.

For some types of batteries this charging rate is about 30 per cent of the 5-hour discharge rate in amperes, and continued for a period of 4 days (96 hours).

4. Start the charge and continue at the rate determined in direction 3, keeping the temperature of the electrolyte below 43 degrees Centigrade (110 degrees Fahrenheit).

A bank of lamps affords the best means of regulating the current for this charge, if a 110 volt direct current circuit is available.

5. At the completion of the charge, adjust the specific gravity of the electrotype, if it is not between the limits of 1.280 and 1.300.

6. Wipe off the side and top of the battery tray with waste or a cloth dampened with ammonia in order to remove any electrolyte that may have been spilled.

7. Give the battery a high rate discharge test immediately before putting it in service.

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Questions:

1. *Why is it necessary for the battery to stand 10 to 15 hours after filling before charging?*

2. *Why is this charge continued for so long a period of time? Why at a very low rate of current?*

3. *Why is the battery to be given a high rate discharge test?*

Trickle Charge

1. Determine the charging rate, which is equal to approximately 1 per cent of the finishing rate in amperes. For example, a battery having a finishing rate of 5 amperes will require a current of approximately 0.05 ampere for trickle charge.

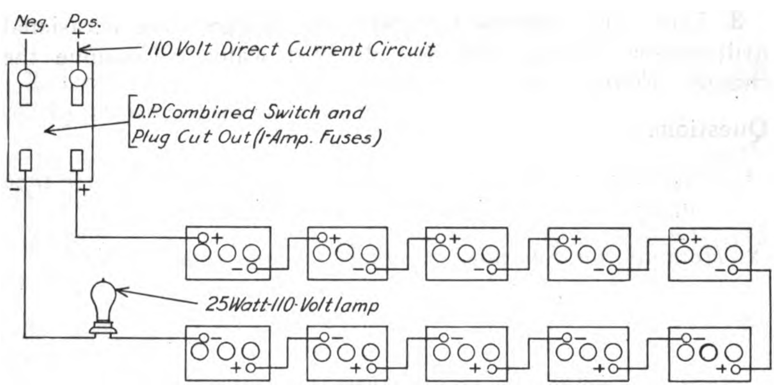


Diagram of Connections for "Trickle Charge." Showing Ten 6-Volt Batteries

Fig. 4

2. Arrange the circuit in accordance with Fig. No. 4, connecting not more than 45 cells in series on a 110 volt direct current circuit. This corresponds to 15 3-cell batteries. The number and arrangement of lamp required to permit of various values of current may be found from the following table:

Lamps for Trickle Charge

(Lamps are rated at 110 volts. The combinations may be used on circuits of from 105 to 115 volts)

Number of Cells in Series	Approximate Current—Ampere		
	0.05	0.10	0.15
3	5 15-watt lamps in series	3 25-watt lamps in series	2 25-watt lamps in series
30	2 15-watt lamps in series	1 25-watt lamp	1 25-watt lamp
45	1 15-watt lamp	2 25-watt lamps in parallel	3 25-watt lamps in parallel

3. Every two months interrupt the charge, take occasional hydrometer readings and add distilled water. Continue the charge. Filling plugs are to be in place.

Questions:

1. *What are the advantages, if any, in using lamps rather than other forms of resistance for regulating the current?*

2. *How do you determine whether charging rate is right?*

AUTOMOTIVE DEPARTMENT

Storage Battery Care and Maintenance

Adjusting Strength of Electrolyte Lead Acid Battery

Directions:

1. Give the battery an equalizing charge.

2. Have on hand a quantity of electrolyte of specific gravity 1.285 to 1.300 at 25 degrees centigrade if the gravity is to be raised, or a quantity of distilled water if the gravity is to be reduced.

About one quart of electrolyte or distilled water is suggested as a sufficient quantity.

To Raise Specific Gravity

3. Draw the electrolyte down to the top of the plates in each cell by means of the hydrometer syringe.

The electrolyte thus drawn out may be put in a clean bottle and preserved for future use.

4. Fill each cell to the proper level with electrolyte prepared as directed in 2.

5. Give the battery a charge at the normal rate for say, one hour.

To Lower the Specific Gravity

6. Proceed as directed above but fill the cells with distilled water instead of electrolyte as specified in 4.

Note: The above directions assume that the specific gravity of all cells is practically the same before making the adjustment. Sometimes it may be necessary to adjust the gravity of one cell only, or a different amount of adjustment may be required for each cell. Experience is the best guide.

Questions:

1. *Why is the battery to be given an equalizing charge before making an adjustment of specific gravity?*
2. *Why is it desirable to give the battery a short charge after making one adjustment?*

SB—10—10M—9-20

AUTOMOTIVE DEPARTMENT

Storage Battery Care and Maintenance

Filling a battery with electrolyte

References:

"Exide" Manual, Electric Storage Battery Co., Form 1296, 1919, pp. 22, 25.

Bulletin 850X, Edison Storage Battery Co., p. 22.

Directions:

Lead-acid Battery

1. Prepare the required amount of electrolyte of specific gravity 1.285 to 1.300 or as specified on the manufacturer's tag attached to the battery.

2. Fill each cell to the level specified on the tag, usually about ⅜ inch above the top of the plates. A rubber syringe is convenient for this purpose.

3. Allow the battery to stand from 10 to 15 hours. Watch the level of the electrolyte and add more electrolyte to restore the level if it has fallen.

4. Wipe off the top and sides of the battery tray with a cloth dampened with dilute ammonia.

5. Give the battery an equalizing charge.

6. Adjust the strength of the elctrolyte, if the specific gravity is not between 1.285 and 1.300, or as otherwise specified, at the end of the equalizing charge.

Questions:

1. *What kind of vessels will you use for holding the electrolyte? Why?*
2. *Why do you allow the battery to stand for so long a time after filling?*
3. *What causes the electrolyte to disappear, apparently, while the battery is standing?*
4. *How would you test the level of the electrolyte?*

Edison Battery, Electrolyte Renewal

1. When ordering renewal electrolyte from the Edison Storage Battery Co. state the type and number of cells, as a battery of 42 Type A6 cells.

SB—12—10M—9-20

2. Do not attempt to do any work on the battery except cleaning, until the new electrolyte has been received.

3. Discharge the battery to zero voltage.

4. Remove the old electrolyte by pouring about half of it out of the cell. Shake the cell vigorously and empty out the rest of the electrolyte. Do not allow the cells to stand empty.

5. Fill the cells immediately with the new electrolyte, using a glass or enamel ware funnel, or a syphon, direct from the drum, of clean rubber tubing. Fill each cell to exactly the right height.

6. Assemble the cells in the trays and connect the battery for service.

7. Give the battery an overcharge in accordance with the instructions of the Edison Storage Battery Company.

Questions:

1. *What indications are there that the battery requires new electrolyte?*
2. *What do you understand by discharging the battery to zero voltage? How would you do this?*
3. *How would you arrange a syphon for filling cells from the drum?*
4. *Is the new electrolyte the same as that first used in the battery?*

AUTOMOTIVE DEPARTMENT

STORAGE BATTERY CARE AND MAINTENANCE

Inspecting battery

Directions:

1. Make an inspection of the battery and an analysis of the work to be done, based on the following.

Questions:

1. *How should the battery be removed from the car? What precautions must be taken?*
2. *What should be done, if the top of the battery is covered with acid-soaked dirt?*
3. *Why should you wipe the outside of the battery clean with cotton waste, or a cloth, damp with a solution of washing soda or dilute ammonia?*
4. *What is liable to happen if the soda or ammonia gets into the battery? How will you prevent this happening?*
5. *What may be the results of the top of the battery being covered with acid-soaked dirt?*
6. *What should be done if the covers are found to be cracked? What will happen to the battery, if the covers are cracked?*
7. *What should be done if the sealing compound is found to be cracked or broken away from the tray?*
8. *How should a cracked or broken jar be located? What should be done?*
9. *What should be done if the tray is acid soaked?*
10. *What should be done if the terminals or intercell connectors are found to be corroded? Which terminal will have the greater amount of corrosion? Why?*
11. *What are the effects of corroded terminals or intercell connectors? Of loose terminals and connectors?*

SB—13—10M—9-20

AUTOMOTIVE DEPARTMENT

Storage Battery Care and Maintenance

References:

Instruction Book of Manufacturer of Particular Outfit in Use.

Directions:

1. Close the alternating current main line and starting switch, also charging switch thereby closing the circuit.

2. Gently rock the rectifier tube until an arc is formed, then open starting switch.

3. Throw the double acting switch into charging position.

4. Regulate the charging current as to voltage and amperage to conform to the number of batteries under charge, by means of the rheostat or other regulating device according to type of rectifier.

Questions:

1. *Why is the tube rocked in starting the rectifier action?*
2. *Explain how the alternating current is rectified into direct current.*
3. *Is it continuous or pulsating?*
4. *Why is a resistance used in starting rectifier?*
5. *What is the function of the reactance coil?*
6. *What is the discharge terminal called?*
7. *What should be done when the rectifier stops functioning?*
8. *What are the intake terminals called?*
9. *Why does not the alternating current cross from one terminal to the other?*

SB—16—10M—9-20

AUTOMOTIVE DEPARTMENT

Storage Battery Care and Maintenance

Tearing Down a Battery

References:

Circular No. 92, Bureau of Standards, 1920, p. 55.

C. A. Waite, The Automobile Storage Battery, 1919, p. 246.

The "Exide" Manual, Elec. S. B. Co. Form 1296, p. 42.

Directions:

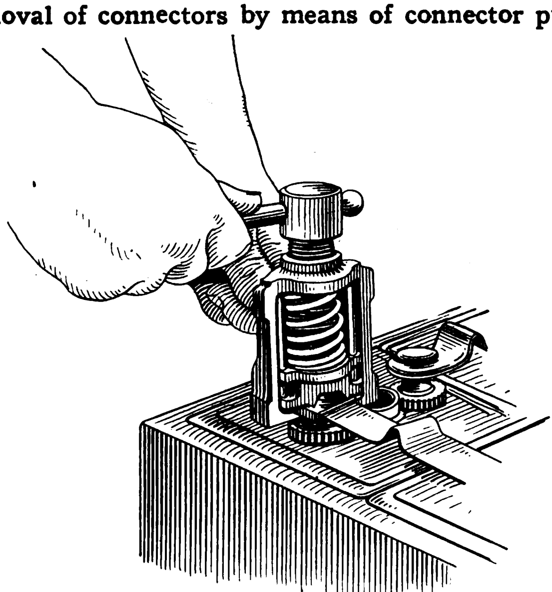
General

1. Clean off the top of the battery thoroughly. A wire brush or a whisk broom may be used to remove dirt, and cotton waste or a cloth dipped with a solution of washing soda or dilute ammonia to wipe off the top and sides of the battery. The soda, or ammonia, neutralizes or "kills" the acid that might harm the battery tray.

2. Make a sketch or diagram showing the relative location of cells, intercell connectors and terminals and give any other information necessary to insure correct assembly.

3. Read and correct the specific gravity and temperature of each cell.

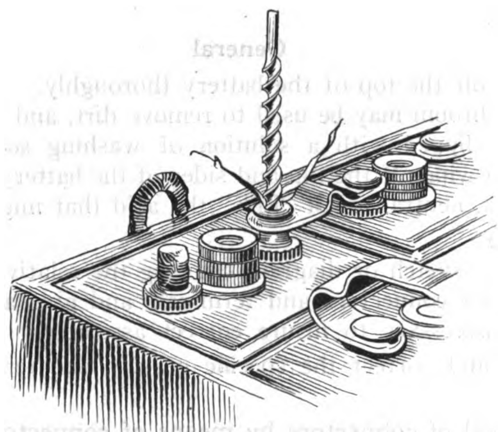
Removal of connectors by means of connector puller



Use of connector puller
Fig. 7

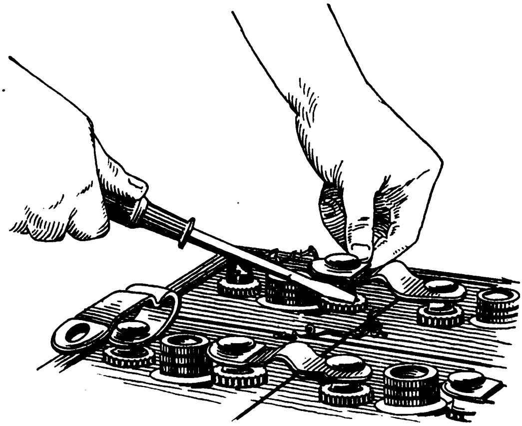
1. Place the puller in a vertical position, Fig. 7 and screw the plunger down gradually until the connector is free from the post. This method is quick and easy but necessitates trimming the terminal post before burning on a new connector.

2. Boring out with wood bit or twist drill. Select a wood bit or twist drill, the former preferred, at least of the same size as the post. This usually is 5/8 inch.



Boring out connector
Fig. 8

3. Mark the center of the post with a prick punch and bore to a depth of about 3/16 inch, Fig. 8. When the right depth has been reached the connector will seem loose and the joint between it and the post may be seen. The filling plug must be in position while boring in order to prevent lead chips getting into the cell.



Prying off connector
Fig. 9

4. Insert a screw driver between the under side of the connector and the sealing nut, if there is one, and pry firmly but gently on the connector, Fig. 9. Repeat this operation first on one side of the post and then on the other, until the connector is free. If there is no sealing nut, place a strip of wood about ½ inch thick across the top of the cell close to the post and use this as a support in prying off the connector. If the boring is not properly done, as for example, the hole is not concentric with the post, heat may be applied gradually to the connector until the lead is softened sufficiently to permit pulling off the connector with a pair of pliers. A blow torch may be used for this purpose. Care must be taken not to put pressure on the cover, as it may be broken easily. In all operations care must be taken not to short circuit the cells by allowing pliers or other tools to come in contact with both posts at the same time.

Questions:

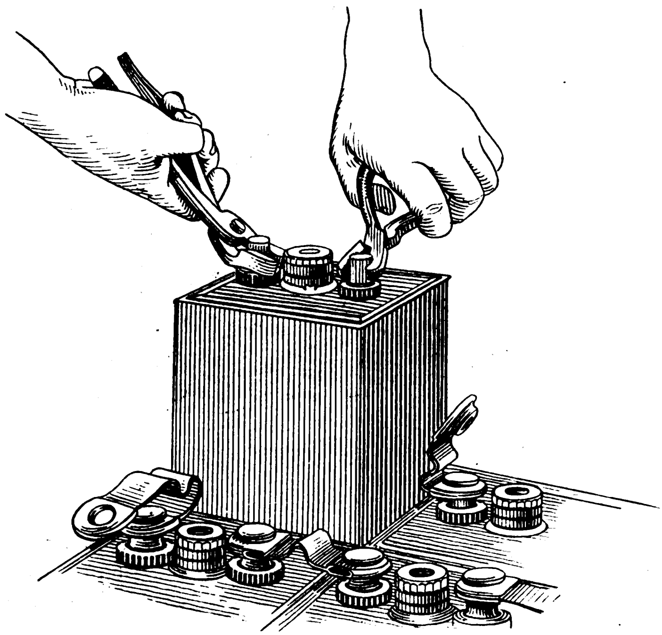
1. *Why is it necessary to trim the posts before burning on a new connector?*

2. *Why is it better to use a wood bit rather than a twist drill when boring out a connector?*

3. *Should the battery be fully charged, fully discharged or partially discharged before starting to dismantle it? Why?*

4. *Which post has more corrosion? Why?*

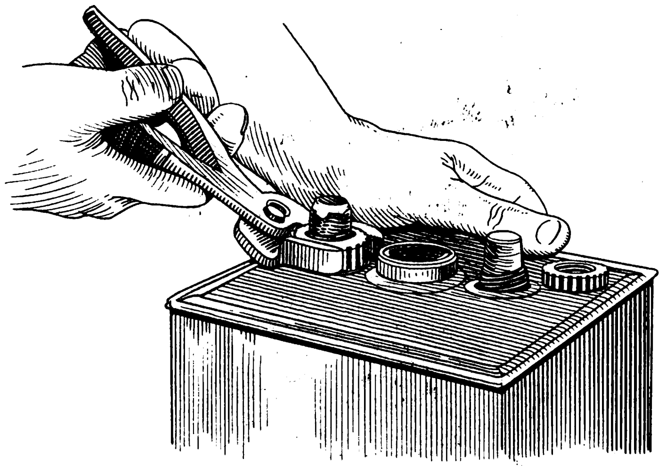
Removal of Cell



Removal of cell
Fig. 10

1. Grasp each post with a pair of pliers and pull vertically, Fig. 10. If the jar sticks, a hot putty knife may be inserted around the edges. This usually will loosen the jar so that it may be pulled out easily.

2. Rest the jar on the edge of the tray so that the pliers may be removed and the cell lifted to a position for the next operation.



Removal of sealing units
Fig. 11

3. Remove the sealing nuts, if there are any, by means of a special wrench, Fig. 11. If such a wrench is not available, use a pair of pliers. Use a monkey wrench or a pipe wrench only as a last resort.

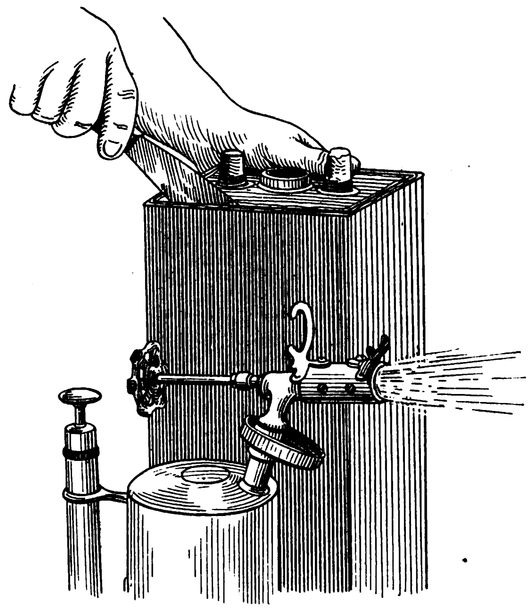
Questions:

1. *What kind of pliers should be used for removing sealing nuts? Why?*
2. *How are sealing nuts held in place?*
3. *What other means are used to make a tight joint where the posts pass through the cover?*

Removal of Cover and Element

1. Remove the vent plug and blow the gases out of the cell. A small hand bellows is excellent for this purpose.

2. Warm the top of the jar, at the top, with the flame from a blow torch.

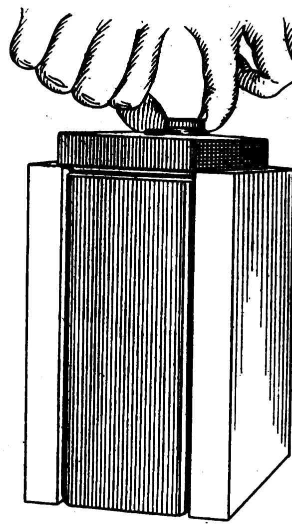


Use of hot putty knife for removing sealing compound
Fig. 12

3. Insert a hot putty knife between the inner edge of the jar and the cover to melt out the compound. This operation should be performed as rapidly as possible, as the compound cools rapidly, Fig. 12.

4. Place the finger in the filling aperture and lift vertically on the cover. If the cover does not come up readily, remove all of the sealing compound possible by means of a hot putty knife and heat the sides of the jar again before pulling on the cover.

5. For a double flange cover, procure two boards about 1 inch thick and ½ inch longer than the height of the jar and rest the side flanges of the cover on these so that the cell is raised above the bench, Fig. 13. Warm the cover all around the edges to soften the compound. Press down firmly on the posts and the element will drop readily from the cover.



Removal of double flange cover
Fig. 13

6. Place the jar, with the cover removed, on the floor with one foot on each side and grasp each post with a pair of pliers Pull the element slowly upward while holding the jar with the feet, Fig. 14.

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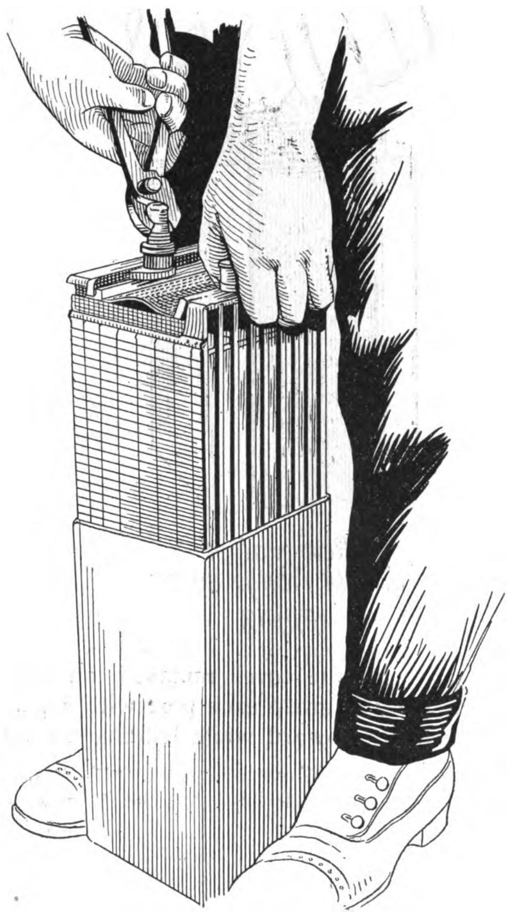
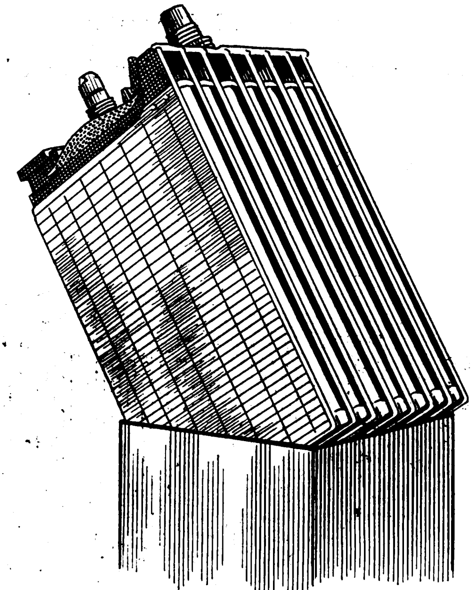


Removal of element
Fig. 14

7. When the element is nearly out, place it slightly out of plumb on the top of the jar and let it drain for about 5 minutes before removing it entirely, Fig. 15.



Draining element
Fig. 15

8. If the negative plates begin to dry and heat, dip the element in water until they have cooled off.

9. Clean the cover thoroughly and wipe off the edges with cotton waste or a cloth damp with dilute ammonia, drying it with a piece of clean waste.

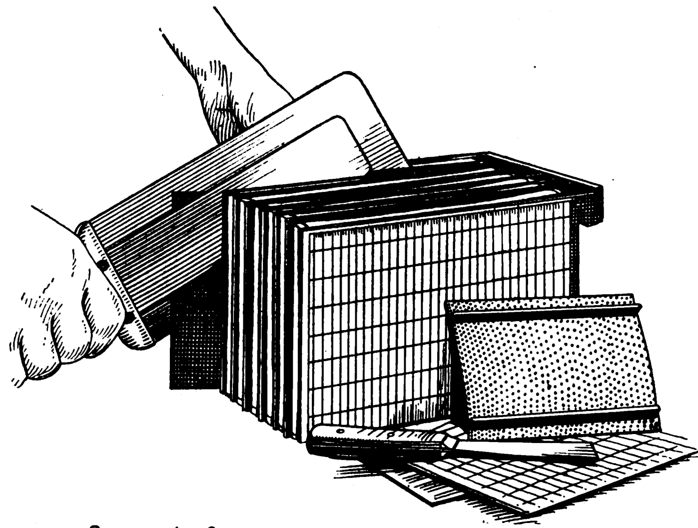
10. Pour the electrolyte out of the jar and wash the jar with distilled water.

Questions:

1. *Why should the gases be blown out of the cell?*
2. *What causes the negative plates to heat?*
3. *Is the heating greatest when the negative plates are charged or discharged? Why?*
4. *Why is it necessary to clean the edges of the cover with dilute ammonia?*
5. *Why is distilled water used for washing out the jar?*

Removal of Separators

1. Place the element with cover removed, on edge of a bench, Fig. 16.



Removal of separators, Use of separator inserter for vehicle type batteries. Splash cover shown in foreground.

Fig. 16

2. Spread the plates slightly and run a thin-bladed knife between the separators and the negative plates.

3. Withdraw the separators, one at a time.

4. If the separators are to be used again, put them in a weak acid solution.

5. Separate the positive and negative groups. If the negative plates are to be used again, do not let them dry but place them in distilled water or electrolyte.

Questions:

1. *Why should the separators be kept in a weak acid solution rather than in water?*

2. *Why is it desirable to keep the negative plates in water or electrolyte, if they are to be used again?*

AUTOMOTIVE DEPARTMENT

STORAGE BATTERY CARE AND MAINTENANCE

Assembling a lead-acid battery

References:

Circular No. 92, Bureau of Standards, 1920, p. 60.

Waite, C. A., The Automobile Storage Battery, 1919, p. 288

The "Exide" Manual, Elec. S. B. Co. Form 1296, p. 46.

Directions:

Putting on Cover

1. Slip the positive and negative groups together without the separators.

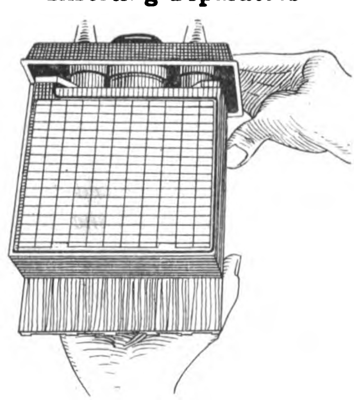
2. Place the covers in hot water for a short while in order to make them somewhat pliable.

3. Wipe the posts with cotton waste damp with dilute ammonia and dry thoroughly with clean waste.

4. Put the soft rubber gaskets, if there are any, on the posts and place the cover in position.

5. Lubricate the sealing nuts, if there are any, with a little graphite mixed to a paste with water and put them on with a special wrench but do not tighten them. Never use vaseline or other grease for lubricating the sealing nuts.

Inserting Separators



Inserting separators
Fig. 17

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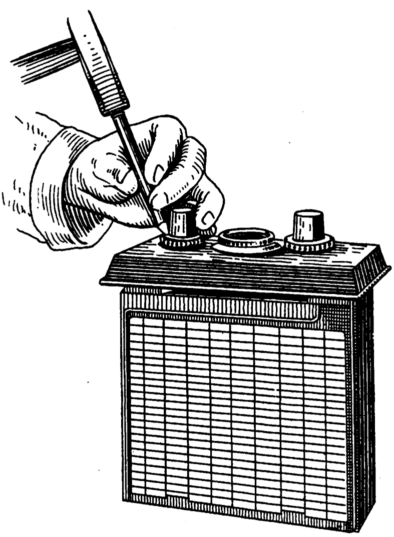
1. Place the group on edge, Fig. 17, and insert the separators from the bottom. One separator goes between each positive and negative plate. Place the separator with the smooth side next to the negative plate and with the grooves vertical. If there are rubber separators in addition to the wood separators, place them next to the positive plates.

2. Stand the element on edge and tap the edges of the separators gently with a block until they project equally on each side of the plates.



Locking sealing units
Fig. 18

3. Tighten the sealing nuts, if there are any, with a special wrench and lock them in position by scoring the thread with a centre punch, Fig. 18.

Questions:

1. *Why are the wood separators placed with the smooth side against the positive plate? With the grooves vertical?*

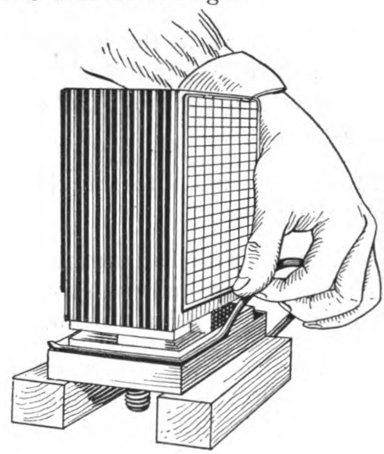
2. *Why are the rubber separators, if there are any, placed next the positive plate?*

Placing Element in Jar

1. Clean the top of the jar thoroughly of any sealing compound and wipe it with waste dampened with dilute ammonia, drying it with clean waste.

2. Place the jar in hot water for a short while.

3. Place the soft rubber buffers, if there are any, in the bottom of the jar, one over each ridge.



Applying compound to double flange cover
Fig. 19

4. For a double flange cover, have ready a string of special sealing compound about $\frac{3}{16}''$ in diameter made by rolling the compound between two boards. Stand the element upside down with the cover ressting on two strips of wood, Fig. 19. Lay the string of the compound all the way around in the channel of the cover and then turn the element right side up.

5. Grip the element near the bottom in order to keep the plates from flaring out, and place them in the jar, taking care that the outside plates do not start down over the outside of the jar.

6. If the element does not fit snugly in the jar, place one or more wood separators between the outside plates and the jar, taking care that the separators are about ½″ narrower than the plates. Place the ribs of the separators next to the jar. Do not crowd the jar so that it bulges.

Questions:

1. *Why is it desirable to have the jar somewhat pliable?*
2. *Why is it desirable to have the jar cleaned throughly and all sealing compound removed?*
3. *What is the object of wiping the jar with waste dampened with dilute ammonia?*

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Sealing the Cell

1. Before sealing, be sure that the surfaces to be sealed are clean and dry.

2. For a single flange cover, heat the sealing compound slowly until it runs, but do not make it so thin that it will run down into the cell between the cover and the jar. The compound must be liquid and not lumpy.

3. Pour the melted compound into the channel between the cover and the walls of the jar.

4. Allow it to cool and fiinish the surface with a hot putty knife. A glossy finished surface may be given to the compound by passing a flame over it after it has become cool.

5. For a double flange cover, the sealing compound should be in the cover channel as directed in "placing Element in Jar", direction 12.

6. Apply heat carefully to the edges of the cover and force it down gently. If too much compound had been used so it oozes out around the cover, scrape off the excess with a hot putty knife while forcing the cover down.

Filling with Electrolyte

1. After a complete renewal of plates and separators, fill the cell with electrolyte of the proper strength as determined from the instruction book of the manufacturer.

2. After a renewal of positive plates and separators only, fill the cell with distilled water instead of electrolyte.

3. Use containers of glass, china, earthenware, rubber or lead only, for electrolyte or distilled water. Never use any metallic container except lead.

4. Pour the liquid carefully through openings until the level rises in the tubes. If the cover is not on the cell, fill to ½″ above top of plates.

Questions:

1. *Why is the cell to be filled with distilled water instead of electrolyte after renewal of positive plates and separator only?*

2. *Why must not metallic containers, other than lead, be used for electrolyte and distilled water?*

Placing Cells in Tray

1. Place the cells in the tray in accordance with the diagram made before dismantling the battery, taking care that the positive and negative terminals come right.

2. For batteries which have wood spacers between cells, take care that these are in position and after all cells are in place tighten the tie bolts.

3. If the cells do not fit tight in the tray, pack them in with thin boards at the ends.

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AUTOMOTIVE DEPARTMENT

Storage Battery Care and Maintenance

Cleaning
Lead Acid Type Battery

References:

Circular No. 92, Bureau of Standards, 1920, Chap. XIV.

"Exide" Manual, Form 1296, p. 45.

Bulletin 850X, Edison Storage Battery Co. p. 21.

Directions:

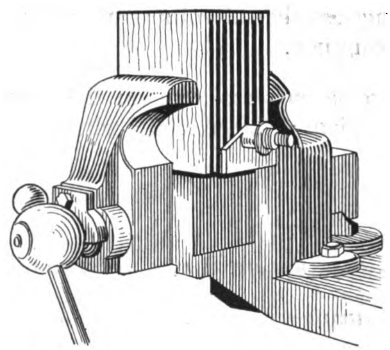
1. Tear down the battery.

2. Place the positive and negative plate groups in distilled water or weak electrolyte.

3. Wash the jars in running water to remove sediment and then rinse with distilled water and set bottom upward on rack to dry.

4. Inspect the jars for cracks.

5. Inspect the plates for sulphation, buckling, looseness or excessive loss of active material.



Pressing negative plates
Fig. 22

6. If the active material of the negative plates is swollen, press this plate group using smooth boards of suitable thickness between each pair of plates and the whole group squeezed between smooth boards in a vise, Fig. 22. Allow the plates to remain some minutes in the vise in order to allow the plates to straighten without undue strain. If the positive plates are badly warped, throw them away, otherwise the loose material adhering to them

should be removed by means of a smooth piece of wood or paddle. If the positive plates are only slightly buckled, they may be replaced as this generally does no harm. Do not wash the plates.

7. If the battery is found to be sulphated, but with the sediment below the bottom of the plates treat it for sulphation before cleaning.

8. In replacing separators use new ones in the case of wood separators and also in the case of defective rubber separators.

9. Assemble the cells and fill with fresh electrolyte.

10. Inspect the tray. If found to be in good condition, wash it with water to which soda has been added. When thoroughly dry, paint it with two coats of acid resisting paint. If a new tray is required, make an accurate sketch of the old one.

11. Assemble the battery.

12. Press the old connectors in place and allow the battery to stand for several hours; 10 hours is a suitable length of time.

13. Charge the battery at the finishing rate. After about 15 minutes, read the voltage of each cell with the current flowing Any cell indicating less than 2 volts is probably connected wrong and should be examined.

14. If found to be correct, burn on the connectors and give the battery an equalizing charge, after which it will be ready for service.

Questions:

2. *Why do you always use new wood separators?*

3. *Why do you always use fresh electrolyte?*

4. *In what state of charge should the battery be before tearing down? Why?*

5. *Why should the plates be immersed in an acid solution?*

6. *Why is the corrugated side of the separators placed next tc positive plate?*

7. *Why do you read the voltage of each cell shortly after start- the charge?*

Edison Battery

1. Remove the battery from the compartment.

2. Clean with steam or compressed air at a pressure of about 70 pounds. A satisfactory arrangement consists of a one inch rubber steam hose about 10 feet long into one end of which has been inserted a piece of iron pipe about 12 inches long with a ⅛" diameter orifice or hole in the end. This orifice can be made by clapping one end of the pipe and drilling out a ⅛" diameter hole. When removing incrustations from the top of the cells, do not let the material fall in between the cells.

3. Cover the top of the cells and the inside and outside of the filling aperture with a light coat of special oil furnished by the Edison Storage Battery Co. The oil can be applied with a small brush. Take care that none of the oil gets inside the lugs or connectors or on the poles. A special vaseline compound can be furnished and used in the same manner, except it must not be allowed to get inside the filling aperture or into the interior of the cell.

4. Coat the cells and trays, occasionally after cleaning, with Esbalite, an alkaline proof insulating paint furnished by the Edison Storage Battery Co. Be sure that cells, trays, and compartments in truck or other vehicles are clean and dry before replacing battery.

Questions:

1. *How often is cleaning required?*

2. *What results do you expect from dirt and dampness on cells or in compartments?*

3. *Why should the oil be kept out of the lugs and connectors and off of other surfaces for electrical contact?*

4. *How does the oil protect the surfaces to which it is applied against the action of the deposit?*

SB—22—10M—9-20

AUTOMOTIVE DEPARTMENT

Storage Battery Care and Maintenance

Preparing electrolyte

References:

For lead-acid batteries

Directions:

1. Determine the amount of electrolyte required, and the specific gravity.

2. Procure a vessel of earthenware or glass, of ample size to hold the amount of electrolyte to be prepared.

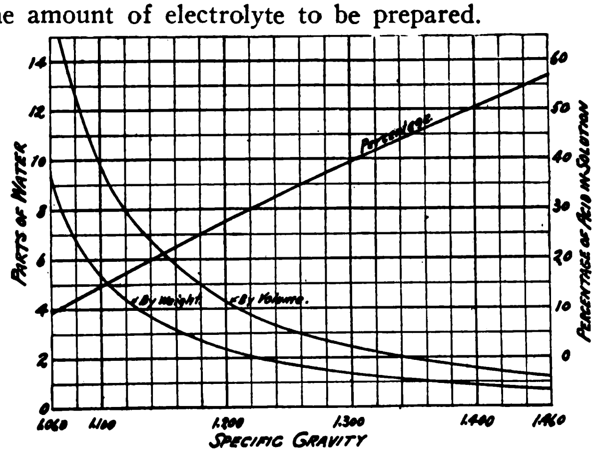


Fig. 23

3. Consult the chart, Figure 23, to determine the quantity of chemically pure sulphuric acid and distilled water required.

Example: Make four quarts of electrolyte of specific gravity 1.260 from sulphuric acid of specific gravity 1.835. By volume. From 1.260 on horizontal line marked "Specific Gravity" follow vertically to the curve marked "By Volume", then horizontally to the left to the vertical line marked "Parts of Water" and read three. Therefore three parts of water will be required for one part of acid. The total mixture will contain four parts and as four quarts are required, three quarts of distilled water and one quart of sulphuric acid are necessary. Proceed in a similar manner if the quantities are to be measured by weight.

4. Pour the acid into the water slowly and stir the mixture with a wooden paddle. Never pour the water into the acid.

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5. Allow the mixture to cool to the temperature of the room before testing the specific gravity.

6. If the electrolyte is to be kept in stock, pour it into a carboy or glass bottle having a glass stopper.

Note: It is well to wear rubber gloves and rubber aprons when mixing electrolyte acid; if large quantities are to be prepared. rubber boots and goggles.

Questions:

1. *What is meant by chemically pure?*
2. *Why is distilled water used?*
3. *Why must the acid be poured into the water?*

For Edison batteries

1. Electrolyte received from the Edison Storage Battery Company in liquid form is ready for use.

2. Prepare the electrolyte received in dry form in accordance with the directions on the package.

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AUTOMOTIVE DEPARTMENT

Storage Battery Care and Maintenance

Correcting hydrometer readings for temperature

References:

Circular No. 92, Bureau of Standards, 1920, p. 37.

"Exide" Manual, Electric Storage Battery Co. No. 1296, Oct. 1919, p. 13.

"The Automobile Storage Battery", 1919, p. 89.

Directions:

For Centigrade temperature

1. When the temperature of the electrolyte is 5 degrees centigrade above 25 degrees, add 3 points to the hydrometer reading; when the temperature is 5 degrees centigrade below 25 degrees, subtract 3 points from the hydrometer reading. Thus: 1.285 at 30 degrees centigrade equals 1.288 corrected to 25 degrees and 1.285 at 20 degrees equals 1.282 corrected to 25 degrees. For every 5 degrees difference, the same amount is to be added to or subtracted from the reading, so for 10 degrees difference, the correction is 6 points and so on.

For Fahrenheit temperature

2. When the temperature of the electrolyte is 3 degrees Fahrenheit above 77 degrees Fahrenheit add 1 point to the hydrometer reading: when the temperature is 3 degrees Fahrenheit below 77 degrees, subtract 1 point from the hydrometer reading. Thus: 1.285 at 80 degrees Fahrenheit equals 1.286 corrected to 77 degrees and 1.285 at 74 degrees equals 1.284 corrected to 77 degrees. For every three degrees difference, the same amount is to be added to or subtracted from the reading, so for 6 degrees difference, the correction is 6 points and so on. Corrections may be obtained immediately from the chart below, arranged for centigrade and Fahrenheit temperatures. Fig. 24.

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The watt is too small a unit for convenient use so the unit called the kilowatt is more frequently used. Some units used in expressing power are:

1 kilowatt (kw.) = 1,000 watts = 1.34 horse power.

1 horse power (h. p.) = 746 watts = 0.746 kw.

1 kilowatt used for 1 hour = 1 kilowatt-hour (kw.-hr.)

1 ampere used for 1 hour = 1 ampere-hour (amp.-hr.)

There is a loss of power in any conductor, carrying a current, due to its resistance. In a direct current circuit, this loss is equal to the product of the square of the current in amperes by the resistance in ohms and is expressed as a formula:

$$\text{Power loss in watts} = I^2 \times R$$

This power loss always produces heat.

The **EFFECTS OF ELECTRIC** current are physical, chemical and magnetic. The physical effect is shown in the glow of the lamps and the spark of the ignition system, the chemical effect in the action of the storage battery and the magnetic effect in the operation of the magneto, the generator and starting motor.

Questions:

1. *Why is alternating current used for carrying power between cities?*

2. *Why is it necessary to use direct current sometimes, as for charging a storage battery?*

3. *What are some of the other uses for direct current?*
4. *A conductor* 25 *feet long has a drop of* 2.5 *volts along its length. What will be the drop in* 100 *feet of this same wire?*

5. *What is the current in a circuit having a resistance of* 1.8 *ohm and a voltage of* 105 *volts?*

6. *What pressure is required to force a current of* 24 *amperes through a resistance of* 5.3 *ohms?*

7. *What is the resistance of a circuit carrying* 15 *amperes at* 220 *volts?*

8. *What is the power loss in a conductor having a resistance of* 0.075 *ohm and carrying a current of* 75 *amperes?*

AUTOMOTIVE DEPARTMENT

Storage Battery Care and Maintenance

Elementary Electricity

References:

W. H. Timbie, Elements of Electricity, 1912, p. 37.

Hobbs, Elliott and Consoliver, The Gasoline Automobile, 1919, p. 131.

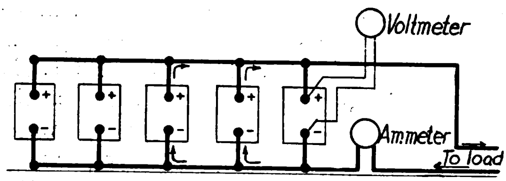
Terrell Croft, Practical Electricity, 1917, p. 53.

Information:

THE NATURE OF ELECTRICITY is not known, but its effects, the laws governing its action and means of controlling and using it for various purposes are well understood. Two methods are used in generating electricity on the automobile, the first is chemical action and the second, electromagnetic induction. Chemical action is the fundamental principle of the storage battery and electromagnetic induction the principle of operation of the magnets and generator.

A DIRECT CURRENT is a current which flows always in one direction. Such a current may vary in intensity (number of amperes) but must always flow the same way. The current from a storage battery is a direct current. An **ALTERNATING CURRENT** is a current which reverses its direction of flow at regular intervals. An alternating current is spoken of with reference to the number of cycles per second thus, a 60 cycle alternating current passes through 60 cycles per second or 120 alternations. The current from the magneto is an alternating current. One way of distinguishing a direct current from an alternating current is to dip the ends of two wires, one from each side of the circuit, into a glass of water into which a teaspoonful of salt has been dissolved. Do not allow the two wires to touch. Fine bubbles of colorless gas will be given off from the negative wire, if direct current; from both wires if alternating current. All materials conduct electricity to a certain extent. There is no known material which does not offer some opposition to the flow of electricity. Materials such as silver, copper and other metals which offer a low resistance are called **CONDUCTORS.** Materials such as glass, porcelain and rubber which offer a high resistance are called **INSULATORS.** A liquid which offers a low resistance is called an **ELECTROLYTE.** The sulphuric acid solution of a lead storage battery and the potassium hydroxide

There are various methods of GROUPING CELLS in a battery to produce various combinations of voltage and current. The most common connection is the series connection in which the positive pole of one cell is connected to the negative pole of the next cell and so on. The end positive and negative poles or terminals of battery correspond to the positive and negative poles of a single cell. This arrangement is shown in Figure 3. The second connection is called the multiple or parallel connection because the positive poles are all connected together and the negative poles are all connected together. The arrangement is shown in **Figure 4.**

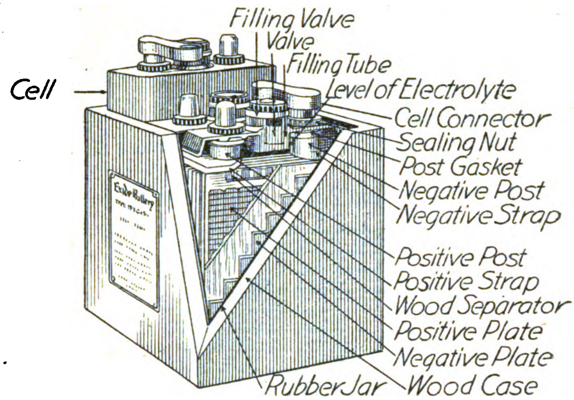


Multiple, or parallel, connection of cells. Total voltage of battery = the voltage of a single cell Total capacity of battery in ampere-hours = the capacity of one cell times the number of cells Arrows indicate direction of flow of current

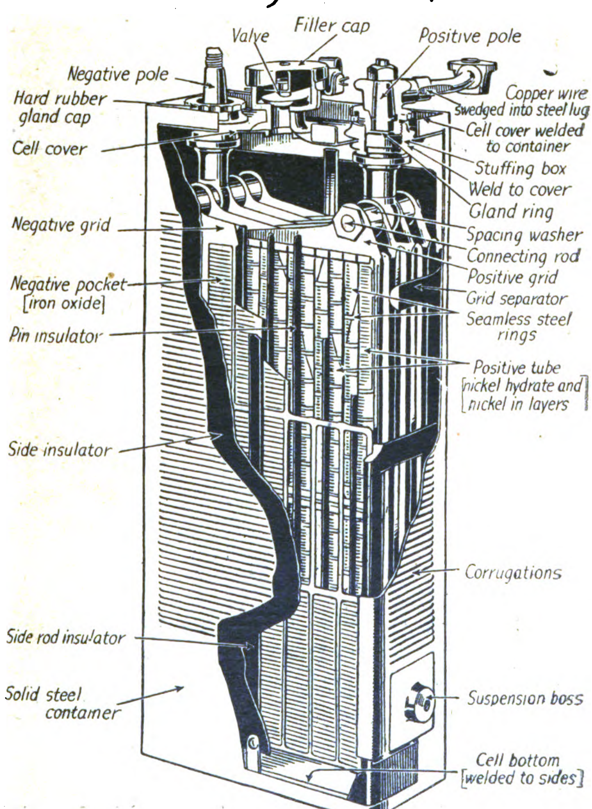
Fig. 4

There are two general TYPES OF STORAGE BATTERIES, known as the lead-acid type and the nickel-iron or alkaline type. An example of the lead-acid battery is the starting and lighting battery for automobiles, and of the nickel-iron battery, the Edison battery used in electrically driven vehicles and for lighting and ignition only for some automobiles and trucks. A lead-acid battery for starting and lighting is shown in Figure 5 and an Edison battery of the vehicle type is shown in Figure 6. Such batteries are called transportable batteries. Other types of lead-acid batteries are stationary batteries such as are used in central stations. These types will not be **discussed here.**

Lead-Acid Batteries

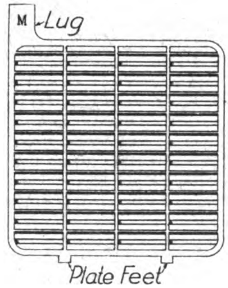


Lead-acid battery for starting and lighting
Fig. 5



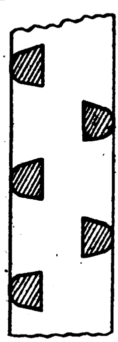
Nickel-iron or Edison cell
Fig. 6

There are two principal TYPES OF PLATES, the Planté and the Faure or pasted plate. Planté plates are used only in stationary batteries. The pasted plate is made on a frame work of lead-antimony alloy called a grid. This consists of a number of light bars running crosswise or horizontally and strengthened by a number of heavier bars running up and



Grid for pasted plate
Fig. 7

down or vertically, Fig. 7. The horizontal bars are staggered as shown in Fig. 8 in order to hold securely the lead compounds with which the grids are "pasted." These compounds set in



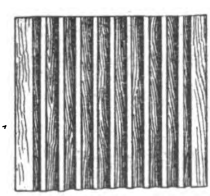
Vertical Section of
Part of the Grid
Fig. 8

drying like cement, forming hardened vertical strips. The plates then go through an electrical and chemical process called "forming" which converts, or changes the paste into the active materials of the plates. The grid in the finished plate acts only as a support for the active materials and as a conductor for the current. The ACTIVE MATERIAL of the positive plate is lead peroxide and of the negative plate, finely divided or sponge lead. The active materials of the

positive plate is of a dark brown color and that of the negative plate is slate gray. The plates are provided with lugs or extensions. A number of positive plates are burned to a strap of lead-antimony alloy forming what is called a positive group, and similarly, a number of negative plates, Fig. 9. For a particular cell the negative group has one more plate than the positive group, consequently both outside plates are negative. Sometimes the outside negative plates are thinner than the inside plates of the same group.

Plate Group
Fig. 9

The plates of a cell are prevented from touching each other by means of SEPARATORS inserted between each positive and negative plate. Separators consist of thin, porous sheets of wood, specially treated to remove substances which would be harmful to the plates. They are usually grooved on the side which is placed next the positive plate, Fig. 10. In some

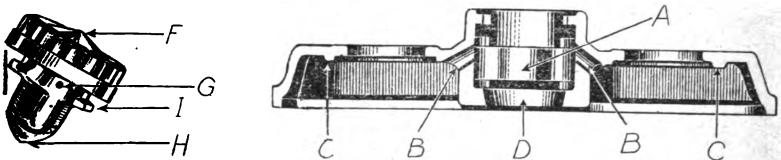


Wood Separator
Fig. 10

types a thin sheet of perforated hard rubber is inserted between the wood separator and the positive plate. There are also other special types of separators, one of which is known as the threaded rubber separator which consists of a sheet of soft rubber compound with a great many cotton threads running transversely through it. No wood separator is used with this special separator.

An ELEMENT consists of the positive and negative plate groups assembled, with the separators.

The JAR, or container for the element and electrolyte of a cell is of hard rubber compound. The bottom of the jar has ribs or ridges upon which the element rests, and which form pockets for the accumulation of sediment thrown off from the plates. The COVER of the jar is of molded hard rubber provided with flanges to which the sealing compound is applied and with holes for the filling tube and the terminal posts of the plate group. One form of cover is shown in Fig. 11.



Filling Plug and Sectional View of one type of Cover with Plug removed
A. Filling Valve
B. Air Passage
C. Air Chamber
D. Filling Tube
F, G, H Filling Plug Vents
I. Filling Plug Thread

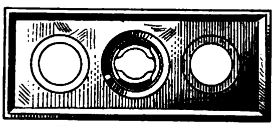


Fig. 11 Cover

There are several methods for making tight joints where the posts pass through the cover. In one form the post is threaded, and a nut, called a sealing nut, is used to force a soft rubber washer around the post against the inside of the cover. In another form several rings are cast around the post and the sealing compound makes a tight joint by flowing into the grooves thus formed.

A CELL is a complete unit consisting of the jar, cover and element, assembled with the electrolyte. A cell has a nominal voltage of 2 volts and a capacity depending upon the size and type. In order to obtain the required voltage, several cells are connected together in series. Thus, a 3 cell battery is a 6 volt battery. The CELL CONNECTORS consist of links of lead-antimony alloy burned to the posts.

The CASE OR TRAY is a container for the cells of a battery. It is of hard wood, strongly built and coated with acid-proof paint. Two handles are provided, one on each end.

A COMPLETE BATTERY consists of a number of cells assembled in a tray and connected together. Batteries for

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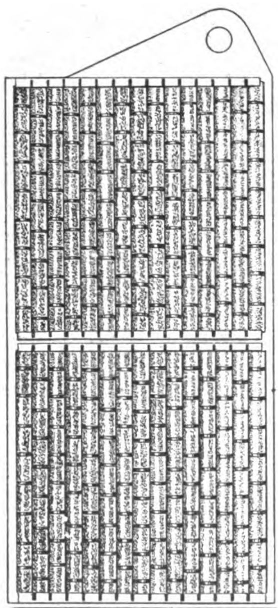
electrically driven vehicles are similar to those for starting and lighting but are much larger.

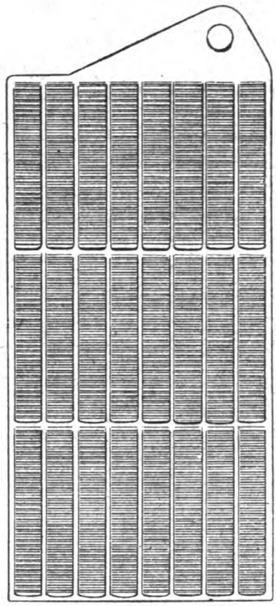
Edison or nickel-iron batteries

The POSITIVE PLATES consist of tubes of perforated sheet steel mounted in steel forms called grids, Fig. 12. The



Positive Plate - Edison Cell
Fig. 12

active material, nickel hydroxide, is tamped into these tubes in alternate layers of flake nickel. The NEGATIVE PLATE consists of thin rectangular pockets of perforated sheet steel mounted in steel grids, Fig. 13. The active materials, iron oxide and metallic iron, are contained in the pockets.



Negative Plate – Edison Cell

Fig. 13

The CONTAINER or JAR is a can of cold rolled steel with corrugated sides and welded seams. The COVER is of the same material welded to the can, and contains a combined filling aperture and gas vent.

TAPERED STEEL POLES, or terminals from the plates project through holes in the cover which are made tight by insulating bushings of fibre. The INTERCELL CONNECTORS consist of insulated flexible copper conductors soldered into the lugs.

All metal parts of the Edison cell are nickel plated.

SEPARATORS between plates and all insulation are of hard rubber.

Chemical reactions

Lead-acid batteries

The ACTIVE MATERIAL of the positive plate is lead peroxide (PbO_2) and of the negative plate, sponge lead (Pb). The ELECTROLYTE is a solution of sulphuric acid (H_2SO_4) and water (H_2O). During the action of charge and discharge the specific gravity of the electrolyte varies. It is highest

when the battery is fully charged and lowest when discharged. The usual range for starting and lighting batteries is from 1.285 to 1.300 charged and from 1.125 to 1.140 discharged, at a temperature of 25 degrees centigrade. For tropical climates these values may be 70 points less. For vehicle type batteries the range is about 10 to 15 points less.

On DISCHARGE OF THE BATTERY the active materials of both plates are converted with lead sulphate ($PbSO_4$); during this process the sulphuric acid is said to diffuse into the plates and water is formed. On CHARGE the reverse action takes place; that is, the lead sulphate is converted into lead peroxide on the positive plate and sponge lead on the negative plate, or reduced as it is called. The sulphuric acid is said to diffuse out of the plates. It is this action which causes the change in specific gravity.

The FORMATION OF LEAD SULPHATE is a necessary part of the process of producing current. At the end of a discharge the sulphate is of such a nature that it is easily reduced by the charging current. If the battery is allowed to stand in a discharged state, the condition of the sulphate gradually changes and the crystals fill the pores of the plates, eventually making the active materials hard and dense. It is this condition which prolongs the time required for a charge and which is referred to when a battery is spoken of as "sulphated." SULPHATION as usually understood is the result of some sort of abuse, as allowing a battery to stand discharged for a considerable time, replacing loss of water by electrolyte or habitual undercharging. It is the negative plates generally which require a prolonged charge to reduce the sulphate. The positive plates are less seriously affected by sulphation but the life may be shortened. Some evidences of sulphation are continued low open circuit voltage and low specific gravity, loss of capacity, inability to take charge, and light color of positive and negative plates. Loss of capacity from sulphation must not be confused with the natural loss of capacity through use.

The VOLTAGE OF THE CELL on open circuit varies from 2.06 to 2.14, depending upon the strength of the electrolyte, the age of the cell and the temperature. The final closed circuit voltage at the end of discharge varies according to the rate of discharge and is approximately as follows:

1 × Normal rate	1.75 Volts per cell
2 × Normal rate	1.70 Volts per cell
5 × Normal rate	1.57 Volts per cell

The average voltage during discharge is approximately as follows:

1 × Normal rate	1.95 Volts per cell
2 × Normal rate	1.90 Volts per cell
5 × Normal rate	1.75 Volts per cell

Figure 14 shows typical performance curves at a 5-hour rate of discharge and constant current charge. Fig. 15 shows the performance with constant potential charge.

Oxygen and hydrogen are given off from the battery while charging. This is called GASSING. The amount of gas increases towards the end of the charge. The gases are of an explosive nature, consequently lighted matches and open flames should be kept away from batteries.

Edison batteries

During the action of charge and discharge there is no change in the composition of the electrolyte as in a lead-acid battery. consequently the specific gravity does not change. The exact chemical changes which take place are not definitely known.

GASSING occurs during the whole period of charge and in small quantities when standing idle. The gasses are hydrogen and oxygen.

THE VOLTAGE OF THE CELL on open-circuit varies from 1.45 to 1.52, depending upon the temperature and the rate of charge. The final closed circuit voltage at end of discharge varies according to the rate of discharge and are approximately as follows:

1 × Normal rate	0.90 Volts per cell
2 × Normal rate	0.80 Volts per cell
5 × Normal rate	0.50 Volts per cell

The average voltage during discharge is approximately as follows:

1 × Normal rate	1.14 Volts per cell
2 × Normal rate	1.05 Volts per cell
5 × Normal rate	0.75 Volts per cell

Fig. 16 shows typical performance curves at a 5-hour rate of discharge, with constant current charge.

Capacity

The capacity of a storage cell is expressed in two ways; as the ampere-hour capacity and the kilowatt-hour capacity. The discharge capacity in amperes per cell is based upon the number of amperes per positive plate, thus, a 9 plate cell which has 4 positive plates will have a discharge capacity of 40 amperes, if the rate is 10 amperes per positive plate. THE AMPERE-HOUR CAPACITY is equal to the product of a specified rate of continuous discharge in amperes and a specified number of hours to a specified final end voltage, thus, at 45 amperes discharge rate and 5 hours time the capacity is:

$$45 \text{ amps.} \times 5 \text{ hrs.} = 225 \text{ amp.-hrs.}$$

THE KILOWATT-HOUR CAPACITY is equal to the product of the ampere-hour capacity and the average voltage during discharge, divided by 1,000. Thus, for a 6 cell battery having an ampere-hour capacity of 90 and an average voltage of 1.95 volts per cell, the kilowatt-hour capacity is:

$$\frac{90 \text{ amp. hrs.} \times 6 \text{ cells} \times 1.95}{1000} = 1.05 \text{ kw. hrs.}$$

The capacity of a cell is less as the discharge rate is increased.

This variation is shown in the following table:

Discharge Current	Time	Capacity	Final Volts
16.5 amps.	5 hrs.	82.5 amp. hrs.	1.77 per cell
24.5 amps.	3 hrs.	73.5 amp. hrs.	1.76 per cell
55.0 amps.	1 hr.	55.0 amp. hrs.	1.71 per cell
90.0 amps.	30 min.	45.0 amp. hrs.	1.65 per cell

This represents a 13 plate starting and lighting cell with electrolyte of specific gravity 1.300. When the discharge is intermittent the capacity is greater than at the same rate of continuous discharge.

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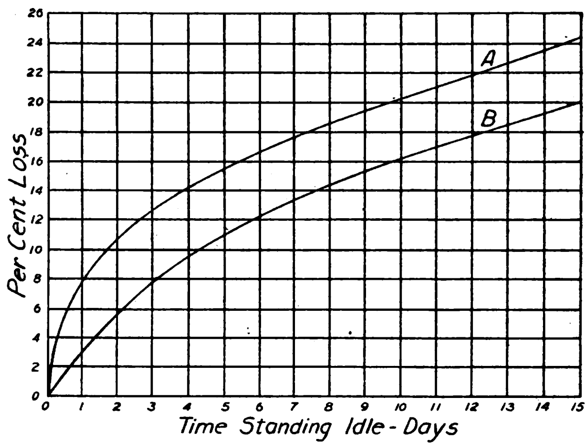
All storage batteries show a loss of capacity standing idle. This is shown in Fig. 17. In addition to this loss, storage batteries show a temporary loss of capacity due to low temperatures, which is greater for the nickel-iron battery.



Curve A, nickel-iron type: curve B, lead-acid type. All cells were maintained at constant temperature of 22°C (71.6°F)

Loss of capacity when standing idle

Fig. 17

Questions:

1. *What parts of the cell constitute the electrodes?*
2. *What kind of current must be used for charging a storage battery? Why?*
3. *Why are Edison batteries not used for starting systems of automobiles?*
4. *Why are the horizontal bars of a lead plate grid staggered?*
5. *Why are the outside negative plates of a group sometimes made thinner than the inside plates?*
6. *What differences are there in the color of the plates of a lead-acid cell when charged and discharged?*
7. *What special types of plates are there for lead-acid cells besides the flat pasted plates? What advantages, if any, do such plates possess?*
8. *What would be the result of any part of one plate group coming in contact with any part of the other plate group in a cell?*

9. *Why is the grooved side of the separator placed next the positive plate?*

10. *Do the grooves run vertically or horizontally and why?*

11. *Why is the perforated rubber separator placed next the positive plate?*

12. *What do the readings of specific gravity of the electrolyte in a lead-acid battery indicate?*

13. *How may lead sulphate be reduced? What is an indication that there is none remaining in the plates?*

14. *What is the first thing to do in treating a sulphated battery?*

15. *Is it possible for a single cell of a battery to be sulphated and the remaining ones to be in normal condition? Why?*

16. *What do open circuit voltage readings mean to you?*

17. *As the positive plate is of lead and contains lead peroxide, why is not this plate a storage battery in itself?*

18. *Why does it not have a local charge and discharge of some magnitude?*

19. *What indications are there of the state of charge of an Edison battery?*

20. *Why is the closed-circuit voltage measured across the terminals of a battery less than the sum of the voltages of the individual cells?*

21. *Does the amount of gassing give you any indications of the state of charge of a battery and why?*

22. *What are the disadvantages of gassing?*

23. *What advantages are there in using thin plates in a battery? What disadvantages?*

24. *How would you determine the average voltage during the charge or discharge of a battery?*

25. *What is the basis of capacity of a battery?*

26. *Upon what does the capacity depend?*

27. *Why is the capacity of a battery less with a high discharge current than with a low current?*

28. *Why is the capacity of a battery greater with an intermittent discharge current than with a continuous discharge current of the same value?*

29. *Why does a storage battery lose capacity when standing idle?*

30. *What is meant by a sluggish battery?*

31. *What causes a battery to heat when current is flowing? In which type of battery is the heating greatest? Why?*

32. *Why does the capacity of a battery change with the temperature?*

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AUTOMOTIVE DEPARTMENT

STORAGE BATTERY CARE AND MAINTENANCE

Charging

References:

Circular No. 92, Bureau of Standards, 1920, p. 44.
Bulletin No. 177, Electric Storage Battery Co.
Bulletin 850 X, Edison Storage Battery Co., p. 8.

Information:

1 **A CHARGE** is the passing of a direct electric current through a battery in the direction opposite to that of discharge of the battery in order to restore the battery to condition for again delivering current.

2 **DIRECT CURRENT ONLY CAN BE USED FOR CHARGING.** If alternating current only is available, it must be changed into direct current by means of a motor-generator set, a synchronous converter, a mercury are rectifier or a tungar rectifier.

3 The **CHARGING RATE** is the current or number of amperes to be used in charging a battery. This rate is obtained usually from the name plate of the battery where it is stated as two values, the first called the starting rate and the second the finishing rate. It is measured in the charging circuit by means of an instrument called an ammeter, or if incandescent lamps are used in the circuit as resistance, the current may be figured easily when the sizes of lamps are known. Fig. 18 shows an arrangement for charging one battery from a 110 volt circuit, the lamps being rated at 110 volts and 100 watts. It will be seen that the lamps are connected in parallel with each other and the combination in series with the battery. With this arrangement, each lamp will allow about 1 ampere of current to flow through the battery and the com-

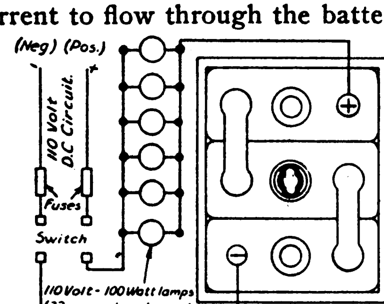


Diagram of Connection for charging one 6-volt battery from 110 volt line
Fig. 18

bination will allow about 6 amperes to flow. Table I shows the approximate current taken by lamps of various sizes. These may be combined to give any value of current desired.

Table I. Approximate current taken by 110 volt lamps

Size Lamp Watts	Current in Amperes				
	Single Lamp	Number of Lamps in Parallel			
		2	3	4	5,
25	0.25	0.50	0.75	1.00	1.25
50	0.50	1.00	1.50	2.00	2.50
100	1.00	2.00	3.00	4.00	5.00
200	2.00	4.00	6.00	8.00	10.00

4. All charges are alike in principle and each is referred to according to its application. A **BENCH CHARGE** is a charge given the battery from a source outside of the car. This charge usually is given at the starting and finishing rate.

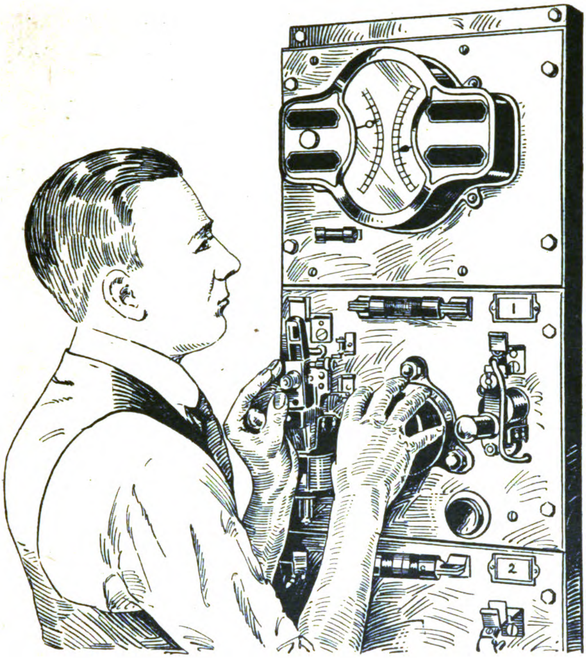
An **EQUALIZING CHARGE** is a charge given a battery at regular intervals following a bench charge in order to reduce or change all of the lead sulphate in the plates. The charging rate is about one-half the finishing rate. This charge is not applied to starting and lighting batteries except when putting a new battery in service, or when troubles are to be investigated, as the battery ordinarily receives sufficient charge on the car.

A **CONDITIONING** or **INITIAL CHARGE** is a charge given a battery which has been received dry; that is, without electrolyte, before putting it in service. The charging rate is very low and the charge is continued for about four days.

A **BOOSTING CHARGE** is a charge at a high rate for a short time, applied only to vehicle and locomotive batteries. Such a charge is usually given during the noon hour in order to increase the capacity of a battery for work in the afternoon and is seldom complete.

A **TRICKLE CHARGE** is a continuous charge at a very low rate sometimes applied to batteries in wet storage in order to keep them in condition.

5. There are **TWO SYSTEMS OF CHARGING** in general use. The first is called the constant current system because the current is held constant or at one value by means of a rheostat in series with the battery. Fig. 19 shows a typical charging panel with rheostat. The voltage gradually rises



Charging Panel With Rheostat
Fig. 19

during a charge. Fig. 14 in Information Sheet No. 2 shows the characteristics of a constant current charge for a lead battery and Fig. 16 the same data for Edison battery. It will be seen for the lead battery that the voltage gradually rises during the time of charge at the starting rate, then fells abruptly when the current is reduced to the finishing rate, rising again gradually to a nearly constant value at the end of the charge. The change in specific gravity of the electrolyte during charge is shown in this figure. Note the nearly constant increase as the charge progresses. The temperature rises during the charge and it will be noted that it has not reached a constant value at the end of the charge, but is increasing. Such curves as are shown in this figure are called characteristic curves. The second is called the constant potential or constant voltage system beause the voltage is held constant or at one value at the terminas of the battery. Fig. 15 in Information Sheet No. 2 shows the characteristics of a constant potential charge for a local battery. It will be noted that the current is very high at the start of the charge, falling rapidly at first, then

more gradually until the end of the charge, when it has become constant. The specific gravity of the electrolyte rises rather rapidly at the beginning of the charge and then more slowly until the end. The temperature rises rapidly at the beginning of the charge and as the current becomes less, begins to fall. This system is in common use for vehicle and locomotive batteries. In order to limit the current at the start of the charge, a resistance may be inserted in each circuit. Such a system is called a modified or semi-constant potential system.

6. The current which will follow a battery on charge depends upon the difference in voltage between that of the charging circuit and that of the battery. For example, a 6 cell lead battery has a charging voltage of 15 volts. On a 110 volt circuit the difference is 95 volts. This is the voltage to be used in figuring the amount of resistance to be put into the charging circuit. For the constant current system the most economical results are obtained when the **VOLTAGE OF THE CHARGING CIRCUIT** is about 2.5 volts per cell. For the constant potential system the voltage should not be more than 2.4 volts per cell nor less than 2.2 volts per cell at the terminals of the battery. When the voltage of the charging source such as a motor-generator set cannot be adjusted to its proper value, counter cells must be used to reduce its voltage. A higher voltage is required in cold than in warm weather. In practice the voltage at the charging panel may be from 2.5 to 2.75 volts per cell to overcome the voltage drop in the wiring. With the constant potential system a battery in any condition of discharge may be put on charge and it will automatically receive the proper charge without excessive gassing or excessive temperature.

For an Edison battery, charging at constant current is carried on at the normal rate for the full period of time required, usually for about 7 hours or until the voltage becomes constant, at least 1.85 volts per cell. For constant potential charging of Edison batteries, the voltage must be at least 1.70 volts per cell.

7. The temperature of the battery must never be allowed to exceed 43 degrees Centigrade (110 degrees Fahrenheit). In tropical countries the limit is 51 degrees Centigrade (125 degrees Fahrenheit).

8. The specific gravity of the electrolyte is between 1.280 and 1.300 when the battery is fully charged, falling to 1.140

to 1.160 at the end of the discharge. For tropical countries these values are seventy points less.

Questions:

1. *Why can direct current only be used for charging a battery?*
2. *Why are two charging rates used? When, during the charge, do you change from one to the other?*
3. *What is meant by gassing? What effect has it on the charging operation? On the battery?*
4. *How does the equalizing charge reduce all of the lead sulphate in the plates? Why is the charging rate low?*
5. *Why is a battery received "dry" given a conditioning or initial charge? Why at a very low rate?*
6. *How does the trickle charge keep the battery in condition?*
7. *What is a rheostat?*
8. *How would you determine the amount of resistance to use in a circuit? Its ampere capacity?*
9. *Why does the voltage fall when changing from the starting rate to the finishing rate on the constant current system?*
10. *Why does a battery charged by the constant potential system never reach a dangerous temperature? Why does it never gas excessively?*
11. *Why is the heating less with a low rate of current than with a high rate?*
12. *What is a motor-generator set? How do you regulate the direct current voltage? What means are provided for keeping the voltage the same at different currents?*
13. *What is a synchronous converter? How do you regulate the direct current voltage?*
14. *Which is the more efficient machine, the motor-generator set or the synchronous converter? Why?*
15. *What is a mercury arc rectifier? Its principle of operation?*
16. *What is a tungar rectifier? Its principle of operation?*
17. *What limitations have mercury arc and tungar rectifiers for battery charging?*
18. *Why must the temperature in battery be kept below a certain point? Why is this maximum temperature higher in tropical climates?*

use as received. The dry electrolyte is to be prepared in accordance with the directions of the manufacturers. The specific gravity of the electrolyte in an Edison cell should be from 1.200 to 1.220. When the specific gravity of potassium electrolytes has fallen to 1.160, it should be renewed. Sodium electrolytes may be used down to specific gravity 1.130. There is no change in the specific gravity of the electrolyte during charge and discharge of the battery, but a gradual decrease is noticed as the battery is used. The freezing point of this electrolyte is —40° F. Below 0° F. a snowlike condition is apparent.

AUTOMOTIVE DEPARTMENT

Storage Battery Care and Maintenance

References:

Circular No. 92, Bureau of Standards, 1920, Appendix E.

Glossary

ACID: A common name for the electrolyte in lead-acid batteries.

ACTIVE MATERIALS: For lead-acid batteries these are lead peroxide on the positive plate, sponge lead on the negative plate; for nickel-iron batteries these are nickel peroxide in the positive tubes, iron in the negative pockets.

ACID SPACES: Net contents of jar available for electrolyte.

ALKALI: A common name for the electrolyte in the nickel-iron or Edison cell. It is principally potassium or sodium hydroxide.

ALLOY: A combination of lead and antimony used in making the grids of lead-acid batteries.

ALLOY BURNING STRIP: An alloy of lead and antimony used in burning on the connectors of lead-acid batteries.

AMMETER: An instrument for measuring electric current.

AMPERE: The unit of electrical current.

AMPERE-HOURS: The product of the current in amperes by the time in hours. The ampere-hour is frequently used as the unit of capacity for storage batteries.

AMPERE-HOUR CAPACITY: The number of ampere-hours which can be delivered by a battery under normal conditions of temperature and at any rate of discharge.

AMPERE-HOUR EFFICIENCY: The ratio of the ampere-hours of output to the ampere-hours of input.

ANTIMONY: A metal alloyed with lead to improve its mechanical properties for making grids.

ARC BURNER: A pointed carbon rod used for lead burning.

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AVERAGE VOLTAGE: The average value of the voltage during the period of charge or discharge.

BAFFLE PLATE: (Cover). A perforated disk used in some forms of filler caps to prevent excessive loss of electrolyte through the vent.

BATTERY: A group of electrically connected cells.

BOLTED CONNECTOR: A form of connection in which the terminal post may be threaded and the connectors attached by bolts or nuts or flat with hole to take a bolt and nut.

BOOSTING CHARGE: A charge at a high rate for a short period. Such a charge is seldom complete.

BRIDGES: Vertical supports for the plates in the bottom of the jar. The space between the bridges allows for the collection of sediment. These are also called ribs, rests or plate supports.

BUCKLED PLATE: A distorted plate.

BURNING: A common expression for the welding of lead terminals and connections, and seams in lead-lined tanks.

BUSHINGS: Fiber collars of distinctive colors around the terminal posts of Edison cells. These are used for insulation and to indicate polarity.

CADMIUM: A piece of metallic cadmium used as an intermediate electrode for determining the potentials of the positive and negative plates separately of a lead-acid cell.

CAPACITY: The rating of a battery usually expressed in ampere-hours, at a given rate of discharge. It may also be expressed in watt-hours. The temperature should be specified.

CAUSTIC POTASH: Potassium hydroxide used in electrolyte in Edison cells.

CAUSTIC SODA: Sodium hydroxide commonly used in electrolyte in Edison cells as a substitute for potassium hydroxide.

CELL: The complete unit of a battery. It consists of the positive and negative plates with separators, terminals, electrolyte, and container.

CHARGE: The restoration of the active materials of a

battery by passing a direct current through it in the opposite direction to that of the discharge.

CHARGING RATE: The proper value of current, expressed in amperes, to use in charging a battery. The value of the current first used in the constant current method of charging is usually called the starting rate, the lower value, the finishing rate.

CHEMICALLY PURE: A term applied to the material for the electrolyte indicating the absence of injurious impurities. It does not mean 100 per cent strength, as chemically pure acid and distilled water is chemically pure solution, although dilute.

CLEANING: Removal of the sediment in the bottom of jars of lead batteries. When cleaning is done, minor repairs such as straightening plates, renewing separators, etc., are usually made. For the Edison battery this word refers to the removal of the deposit on the top of the jars by means of a jet of steam or compressed air.

CLOSED CIRCUIT VOLTAGE: The voltage at the terminals of the battery when current is flowing.

COMPOUND: The material used for sealing the covers to the jars of portable type batteries.

CONDITIONING CHARGE: The charge given a battery before putting it in service. This is sometimes called a freshening charge.

CONNECTOR PULLER: A device for removing a burned on connector of a lead cell. For an Edison cell a similar device is called a jack.

CONNECTORS: The connections to the terminals of the cells. These may be intercell connectors, intertray connectors, or connectors to the external circuit.

CONSTANT CURRENT CHARGE: A charge in which the current is maintained constant at its proper value. For lead batteries this usually involves two rates, called the starting and finishing rates.

CONSTANT POTENTIAL CHARGE: A charge in which the voltage is held at a constant value at the terminals of the battery. To limit the initial current, a fixed resistance

may be inserted in each charging circuit. Such a system is called a "modified constant potential system."

COUNTER CELLS: These cells contain grids or unformed plates, and therefore have practically no capacity. In order to carry the current they must have the same number of plates of the same size as the rest of the battery. They may be used to reduce the voltage of a constant potential charging circuit when it is excessive, since this cannot be satisfactorily done by resistance. They may be used to reduce the voltage of a constant current charging circuit to avoid waste of energy in a rheostat.

COVER: The top of the jar, usually made of the same material as the jar itself. Covers are referred to as flat, molded, or top and bottom, according to the kind. Molded covers may be of the single or double flange type.

CRITICAL TEMPERATURE: A temperature below which an alkaline battery becomes inoperative. This does not refer to the freezing point of the electrolyte.

DENSITY OF ELECTROLYTE: The mass per unit volume. For practical purposes this is about the same as specific gravity.

DISCHARGE: Conversion of the chemical energy of the battery into electrical energy.

DISTILLED WATER: Condensed water vapor.

DRY STORAGE: Storage of batteries without electrolyte.

EFFICIENCY: The ratio of useful output to total input. This may be expressed as the ampere-hour, the watt-hour, or the voltage efficiency.

ELECTROLYTE: A water solution of sulphuric acid for lead batteries and of certain hydroxides for the nickel-iron batteries.

ELECTROMOTIVE FORCE: The total voltage of the cell or battery. This is an open circuit measurement.

ELEMENT: The positive and negative groups with separators, assembled.

END OF DISCHARGE: The point of the discharge at which the voltage of the cell has fallen to a predetermined

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value. The end voltage is usually chosen so that the full useful capacity of the cell is realized.

ENERGY: The ability to do work. The chemical energy of the battery is transformed into electrical energy during discharge which in turn may be transformed into mechanical energy by a motor.

EQUALIZATION: Circulation and diffusion of the electrolyte within the cell. This has an important bearing on the relative capacity at different rates of discharge. A discharged battery is sometimes said to "pick up" due to the equalization of the electrolyte.

EQUALIZING CHARGE: A charge given a lead battery periodically to insure the complete reduction of the lead sulphate.

EVAPORATION: A word used to cover not only evaporation in its true sense, but also loss of water due to gassing.

FAURE PLATE: A pasted plate, such as in a starting and lighting battery.

FILLING APERTURE: The hole in the top of the cell through which the electrolyte or water is introduced. Sometimes called a filling vent.

FILLING PLUG: A device containing a gas vent, for closing the filling aperture of a cell. This is frequently referred to as a filling vent or a filling cap. For lead cells they are commonly of the threaded or bayonet types; for the Edison cell they are frequently hinged.

FINISHING RATE: The rate of charge, expressed in amperes, to which the charging current for lead batteries is reduced near the end to prevent excessive gassing.

FLOODING: Overflowing of the electrolyte. This is generally the result of an excessive quantity of electrolyte.

FLUSHING THE CELLS: Adding water to replace evaporation.

FORMATION: Oxidation and reduction of the raw materials for the positive and negative plates, respectively. Without this process the plates would lack capacity.

FRESHENING CHARGE: See Conditioning Charge. The periodic charge of batteries in wet storage is also called a freshening charge.

GASKETS: Soft rubber rings used to prevent leakage of the electrolyte around the terminal posts of some lead cells.

GASSING: The evolution of oxygen and hydrogen when a battery is on charge. Small amounts of gas are also given off by Edison cells when standing idle and both lead and Edison cells give off gas when reversed, the quantity being greater from the latter.

GRID: A casting of lead-antimony alloy for supporting the active material of a lead battery. A nickel-plated steel frame for holding the tubes and pockets of the Edison battery.

HOLD-DOWNS (Battery): Clamps for holding batteries in position in automobiles, tractors, trucks, or other vehicles.

HYDROMETER: An instrument used for measuring specific gravity. For transportable batteries this is ordinarily contained within the glass barrel of a syringe which is called a "hydrometer syringe."

INPUT: The quantity of electricity, expressed as ampere-hours, or the energy, expressed as watt-hours, received by a cell or battery during the period of charge.

INSULATION: Separation of the metallic parts of opposite polarity by nonconductors such as glass, porcelain, hard rubber, or oil, from each other and from surrounding objects.

INTERNAL RESISTANCE: The total resistance within the cell.

IRON OXIDE: The active material of the negative plate of the Edison battery.

JAR: The container for a cell. This applies particularly to the lead-acid type cells, as the container for an Edison cell is usually referred to as a "can."

KILOWATT-HOURS: The product of power expressed in kilowatts by the time in hours.

LEAD BURNING: A common name for the process of lead welding.

LEAD BURNING STRIP: Lead in convenient form for burning on connectors of lead-acid batteries.

LEAD SULPHATE: A crystalline substance formed on both positive and negative plates during the process of discharge of a lead battery. $PbSO_4$.

LIFE: The period of useful service of a battery.

LOCAL ACTION: Currents within the cell itself due to differences of potential between different parts. In a well designed and constructed battery the local action should be small.

LUG: Projection from grid for connection to the strap.

MERCURY ARC RECTIFIER: A device for transforming alternating into direct current through the medium of a mercury arc.

MOTOR-GENERATOR SET: A transforming device consisting of a motor coupled to one or more generators.

MUD: A common name for the sediment deposited in the bottom of a storage cell.

MULTIPLE CONNECTION: The connection of like poles of two or more cells. This is also called "parallel connection."

NICKEL-IRON BATTERY: A storage battery of the alkaline type, such as are made by the Edison Storage Battery Co.

NORMAL DISCHARGE RATE: The current which the battery will deliver in a specified time. For a stationary battery this is generally the current which the battery will deliver continuously for 8 hours. For transportable batteries this period is commonly taken as about 5 hours.

OPEN CIRCUIT VOLTAGE: The total electromotive force of a cell or battery. This may be measured with a potentiometer or high resistance voltmeter. It does not indicate the state of charge of the battery.

OUTPUT: The quantity of electricity, expressed in ampere hours, or the energy, expressed at watt-hours, delivered by a cell or battery during the period of discharge.

OVERCHARGE: A prolonged charge. Lead-batteries deteriorate if excessively overcharged but overcharges known as equalizing charges are occasionally given to reduce all the sulphate. Overcharges are occasionally desirable for Edison batteries.

OVER-DISCHARGE: Discharge carried beyond the proper end voltage. This is generally harmful to the battery if done repeatedly.

PEROXIDE: An abbreviation of lead peroxide, the active material of the positive plate of a lead cell.

PILOT CELL: A selected cell upon which temperature, voltage, and gravity readings are made and assumed to indicate the condition of the other cells of the battery.

PLATE CAPACITY: The capacity of the individual groups of positive and negative plates. This may be measured by an auxiliary electrode. The rating of a battery is usually expressed on the basis of the rate of discharge per positive plate. The capacity of the negative group in a normal battery is always in excess of that of the positive group.

PLATE FEET: Small lugs at the bottom of the plates of some lead batteries. These rest on the bridges and support the plates.

POINT (of electrolyte density): A common expression for one unit in the third decimal place of a reading of specific gravity.

POLARITY: An electrical condition denoting the direction of flow of current. The discharge current is said to flow from the peroxide or positive plate through the external circuit to the lead or negative plate.

POST: The terminal of a connecting strap.

POLE: The terminal of a cell.

POST WASHERS: Soft rubber gaskets to prevent leakage of electrolyte around the posts.

POTASSIUM HYDROXIDE: One of the principal constituents of the electrolyte for the Edison cell.

POTENTIAL DIFFERENCE: The difference in electrical pressure between two points of a circuit. It is expressed in volts.

POWER: The rate of expenditure of energy. The unit of electrical power is the watt. For a direct current circuit the power in watts is equal to the product of the volts and amperes.

REACTION: Chemical process by which electric current is produced.

RECTIFIERS: Devices for transforming alternating into

direct current through the medium of an arc or the electrochemical properties of the substances used.

REDUCING FLAME: The inside bright tip of the flame as used for lead burning.

RENEWAL SOLUTION: Electrolyte used to replace electrolyte lost or discarded. For lead-acid batteries, this should be of the same composition as the original. Renewal solutions for the Edison battery differ slightly in composition from original electrolyte.

RESISTANCE: The resistance of any direct current circuit is equal to the quotient of the electromotive force by the current flowing. The unit of resistance is called the ohm.

REVERSAL: Change in polarity of a storage cell due to excessive discharge.

RHEOSTAT: A regulating resistance used for controlling the current.

SEALING NUT: A threaded ring around the terminal posts of some lead cells to prevent leakage of electrolyte.

SEALING WELLS: Space between the cover (some molded types) and the side of the jar to hold the sealing compound.

SEDIMENT: Particles of active material deposited in the bottom of a storage cell.

SEDIMENT SPACE: The space in the bottom of the jar below the plates for the collection of sediment during the life of the battery.

SEPARATOR: A device for preventing the plates of opposite polarity from coming in contact within the cell. Separators for portable batteries of the lead-acid type may be of wood suitably treated, smooth or corrugated; of thin sheets of hard rubber, slotted or perforated, sometimes with soft rubber, ribs; or of threaded rubber in which cotton threads run transversely to the surface of the separator. When the perforated hard-rubber separators are used they are generally in combination with wood separators. Separators for Edison cells consist of hard-rubber rods and strip and plain sheets. These are referred to as pin insulators and side insulators, respectively.

SEPARATOR INSERTER: A special tool for the insertion or removal of the wood separators of a lead-acid battery.

SERIES CONNECTION: The connection of the positive of one cell to the negative of the adjoining cell throughout the battery.

SHEDDING: Loss of active material from the plates of a lead battery. The shedding of active material is a gradual process, the particles falling to the bottom of the cell.

SHORT CIRCUIT: The contact of plates of opposite polarity within the cell. This may be due to the breaking down of the separator, the accumulation of sediment in the bottom of the cell or the bridging of a separator by foreign material felling through the vent.

SLUGGISH BATTERY: A battery deficient in capacity, due to period of idleness.

SODIUM HYDROXIDE: A common ingredient of the electrolyte for Edison cells.

SPACERS: Blocks of wood used between the plates of a group of lead cells when the group is shipped or when the plates are being straightened.

SPECIFIC GRAVITY: The ratio of the weight of a given volume of a liquid to the weight of the same volume of water at a definite temperature. It is usually measured in storage-battery work by a hydrometer. When the specific gravity is 1.280 it is usually spoken of as twelve-eighty acid. One unit in the last decimal place is called a point; that is, 1.280 and 1.288 differ by eight points.

SPLASH COVER: A perforated sheet of rubber placed over the top of the plates in some forms of lead batteries.

SPINGE LEAD: The active material of the negative plate of a lead battery.

SPRAY: Fine particles of electrolyte thrown out of the cell by the gas bubbles when charging.

STABBERS: Sharp points on ends of voltmeter leads for making connection to the terminals of the cells; also called "prods."

STRAP: A lead or lead-antimony casting for connecting the plates of a group. The individual plates are burned to the strap. The terminal post is usually cast with strap. Straps having a central round terminal are called pillar-post straps.

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Straps with terminals in the form of an inverted L are called plate straps. Straps are sometimes called "Cross bars."

SULPHATE: A common name for lead sulphate formed during the discharge of a lead cell.

SULPHATION: A common name for the formation of hardened sulphate in a lead cell resulting from improper treatment.

SULPHURIC ACID: The principal ingredient of the electrolyte for a lead storage battery. The commercial grade is not sufficiently good for this use.

SYNCHRONOUS CONVERTER: A machine which converts from alternating to direct current or vice versa. It has a single armature winding with commutator and slip rings.

TAPER CHARGE: A constant potential charge.

TEMPERATURE: Temperature is usually expressed in terms of one of three scales: Centigrade, Fahrenheit, or Reaumur. Temperatures expressed in one scale may be easily converted to the others by the following relations in which C°, F° and R° represent temperatures in these scales, respectively:

$$F^\circ = 9/5\, C^\circ + 32$$
$$C^\circ = 5/9\,(F^\circ - 32)$$
$$F^\circ = 9/4\, R^\circ + 32$$
$$C^\circ = 1.25\, R^\circ$$
$$R^\circ = 3/9\,(F^\circ - 32)$$
$$R = 0.8\, C^\circ$$

TERMINALS: Fittings to provide electrical connection to storage cells or batteries. These vary with the size and kind of the battery as well as with the manufacturer. Taper terminals are made in rights and lefts with different tapers for the positive and negative. Other common forms are the cable and bolt terminals. Tray terminals are commonly of the wing nut or box types. In addition to those mentioned there are many other kinds.

THERMOMETER: An instrument for registering temperature.

TRICKLE CHARGE: A charge at very low rate used when lead batteries are in wet storage.

VALVE: Part of the gas vent on an Edison cell. It permits the escape of gas from within, but prevents the escape of spray or the ingress of foreign material. A ring in the filling aperture of the Exide cell. Its purpose is to prevent overfilling the cell.

VEHICLE BATTERIES: Storage cells for the propulsion of vehicles, trucks and tractors. In the larger sizes they are spoken of as tractor or locomotive batteries according to the use.

VENT PLUGS: Plugs to close the filling apertures or vents in the top of the cells.

VOLTAGE: Electrical pressure. The unit is the volt. The total voltage of a cell is called its electromotive force, but the voltage at the terminals when a current is flowing is the potential difference. Similarly the fall in voltage across any part of the circuit is the potential difference.

VOLTAGE EFFICIENCY: The ratio of the average voltage of the cell or battery on discharge to the average voltage on charge. The average voltage is the average determined for the entire period of charge or discharge.

VOLTMETER: An instrument for measuring voltage.

WASHING: A common word used occasionally in place of cleaning.

WATT: The unit of electrical power. The watts expended are equal to the product of the electrical pressure in volts by the flow of current expressed in amperes.

WATT-HOUR CAPACITY: The capacity of a cell expressed in terms of watt-hours. The watt-hour capacity is equal to the ampere-hour capacity multiplied by the average voltage during discharge.

WATT-HOUR EFFICIENCY: The ratio of the watt-hours of output to the watt-hours of input of a battery.

WATT-HOUR METER: An instrument for measuring watt-hours.

WET STORAGE: Storage of cells containing electrolyte.

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